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# FINAL DRAFT
# FEASIBILITY STUDY, PHASE II
# GROUNDWATER CONTAMINATION
# INDUSTRIAL TRANSFORMER SUPERFUND SITE
# HOUSTON, TEXAS

001236

Prepared in Cooperation with
Texas Water Commission
U.S. Environmental Protection Agency

July 1988

Prepared by:

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The preparation of this report was financed by grants from the U.S. Environmental Protection Agency through the Texas Water Commission.

1016382

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21 July 1988

Ms. Sherry Fuerst
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202-2733

Dear Sherry:

Enclosed please find one final draft copy of each of the following reports pertaining to Phase II at the Industrial Transformer Superfund site:

- RI,
- FS, and
- QA/QC Report.

Please call me if you have any questions.

Sincerely,

Thomas W. Hoskings

Thomas W. Hoskings, Ph.D., P.E.
Department Head

TWH:pmb

Enclosure

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# EXECUTIVE SUMMARY
# FEASIBILITY STUDY, PHASE II
# GROUNDWATER CONTAMINATION
# INDUSTRIAL TRANSFORMER SUPERFUND SITE
# HOUSTON, TEXAS

## Introduction

Radian Corporation was contracted by the Texas Water Commission (TWC to conduct a Remedial Investigation (RI)/Feasibility Study (FS) at the Industrial Transformer Superfund (ITS) site in Houston, Texas. The objective of the RI/FS was to assess the nature, degree and extent of contamination at the Industrial Transformer site, and to identify and evaluate remedial solutions to the contamination. Site sampling and investigation activities were performed from January 1988 to April 1988. The purpose of this report is to document the findings of the feasibility study for trichloroethene (TCE) contamination of groundwater and subsurface soils at the site. 001248

## Background

The ITS site is located less than a mile east of the Astrodome/Astroworld complex on I-610 South Loop West, inside the City of Houston. Access to the ITS site is gained by the freeway feeder road to the north, Knight Street to the west, Mansard Road to the south and South David Street to the east.

The site area is a mix of residential, commercial and light industrial facilities. Within a one-mile radius, a light industrial/commercial business area is located most closely to the site, then the recreational complexes of Astroworld and Astrodome and finally a mix of private, single and multi-family dwellings further away from the site. The residential population is about 2,000, and a maximum traffic of 100,000 persons per day may move within the one-mile radius due to recreational activities associated with the Astrodome and Astroworld.

As early as 1971, an unincorporated company, the Industrial Transformer Company, owned and operated by Mr. Sol Lynn, was located at this site. A City of Houston inspector noticed that workers at the company poured oil out of dismantled electrical transformers onto the ground. In the fall of 1971, Mr. Lynn was given a series of 7-day notices to confine oil and grease to his property. Subsequent inspections revealed no corrective action at the site. On September 11, 1972, the State of Texas brought suit against Mr. Sol Lynn, on charges of illegally discharging industrial waste into Brays Bayou. Mr. Lynn was ordered to pay a $100 fine.

In the fall of 1981, a City of Houston work crew noted strong chemical odors while installing a waterline adjacent to the property owned by Mr. Lynn. The property, though still owned by Mr. Lynn, was leased to Mr. Ken James, owner of Sila-King, a reputed chemical-supply house. An inspection later that day by representatives of Texas Water Commission (TWC) and the City of Houston Department of Health showed about 75 empty drums scattered about the property at the addresses 1415, 1417, and 1419 South Loop West. Most of the drums, labeled "trichloroethene", were empty and punctured.

Various regulatory agencies and the property owner collected a total of 101 soil samples and in 1984, the site was ranked for corrective action through the Superfund program October 5, 1984.

The consultant for the remedial investigation/feasibility study work, Radian Corporation, was selected on May 27, 1986. The RI/FS contract was executed on June 30, 1986. Amendment No. 1, authorizing Phase II - further investigation and feasibility study at the ITS site, was executed October 28, 1987. As part of the RI, field work approved in the work plan was initiated on January 14, 1987.

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## Results of the Remedial Investigation

The remedial investigation consisted of a program of water, soil and sediment sampling completed by Radian to identify the lateral and vertical extent, concentration level, and volume of contaminants. The first phase consisted of collecting soil, sediment, air, surface water, and groundwater samples that were analyzed for polychlorinated biphenyls (PCBs) and TCE. The results of Phase I field work are documented in the Final Site Investigation Report (Radian, 1988), and they indicate that approximately 0.75 acres of soil to a depth of 2 feet will require remediation. The results of TCE sampling from Phase I are shown in Table 1.

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Phase II of the investigation consisted of installing 3 monitor wells in the intermediate water-bearing unit, performing 20 cone-penetrometer soundings, and collecting water samples in the uppermost water-bearing unit. Both soil and water samples were collected from the monitor wells. Table 2 summarizes the data collected in Phase II and Figures 1 through 4 show the data.

## Statement of Problem

TCE is the principal contaminant at the site in the subsurface soil and groundwater, and the EPA has classified TCE as a possible carcinogen. The major concern is that exposure to TCE may impact human health and the environment. The potential exposure pathway is ingestion of groundwater, and the EPA and the TWC have set a cleanup criterion at 5 ppb TCE to meet the objectives of minimizing the potential for exposure to TCE-contaminated groundwater and protecting uncontaminated groundwater for current and future use. This FS addresses only those actions effective in remediating the groundwater to the cleanup criterion.

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TABLE 1. SUMMARY OF TCE SAMPLES AND RESULTS
PHASE I WORK

| Sample Origin | Sample Type | No. of Samples | Parameter Analyzed | ** Range of Concentration Levels (ppm) | Comments |
|---|---|---|---|---|---|
| Soil & Sediment | Soil | 4 | TCE | 0.02 - 2 | |
| | | 1 | POP | | TCE:0.0018 p[illegible] |
| Shallow Soil Boring | Soil | 18 | TCE | 0.0051-150 | |
| | | 4 | POP | | TCE:0.003-57[illegible] |
| Deep Soil Boring | Soil | 4 | TCE | 0.0077-43 | |
| | | 1 | POP | | TCE:240 ppm |
| Monitor Well | Soil | 4 | TCE | 15-2000 | |
| | | 1 | POP | | TCE:12 ppm |
| Groundwater | Water | 15 | TCE | 0.0007-500 | |
| | | 4 | VPOP | 1.5-320 | |
| Stormwater | Water | 2 | POP | | TCE:0.0026 ppm |

TCE - trichloroethene
POP - Priority Organic Pollutants, including TCE
VPOP - Volatile Priority Organic Pollutants

** - Values have been rounded.

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TABLE 2. SUMMARY OF SAMPLES AND RESULTS
PHASE II WORK

| Sample Origin | Sample Type | No. of Samples | Parameter* Analyzed | Range of Concentration Levels (ppm) |
|---|---|---|---|---|
| Int. Monitor Well | Soil | 30 | TCE | ND - 600 |
| Int. Monitor Well | Water | 3<br>6 | PCB<br>TCE | <0.4<br>0.005 - 14 |
| Shallow Monitor Well | Water | 12 | TCE | ND - 550 |
| Cone Penetrometer | Water | 20 | TCE | ND - 790 |

* TCE = trichloroethene
PCB = polychlorinated biphenyls

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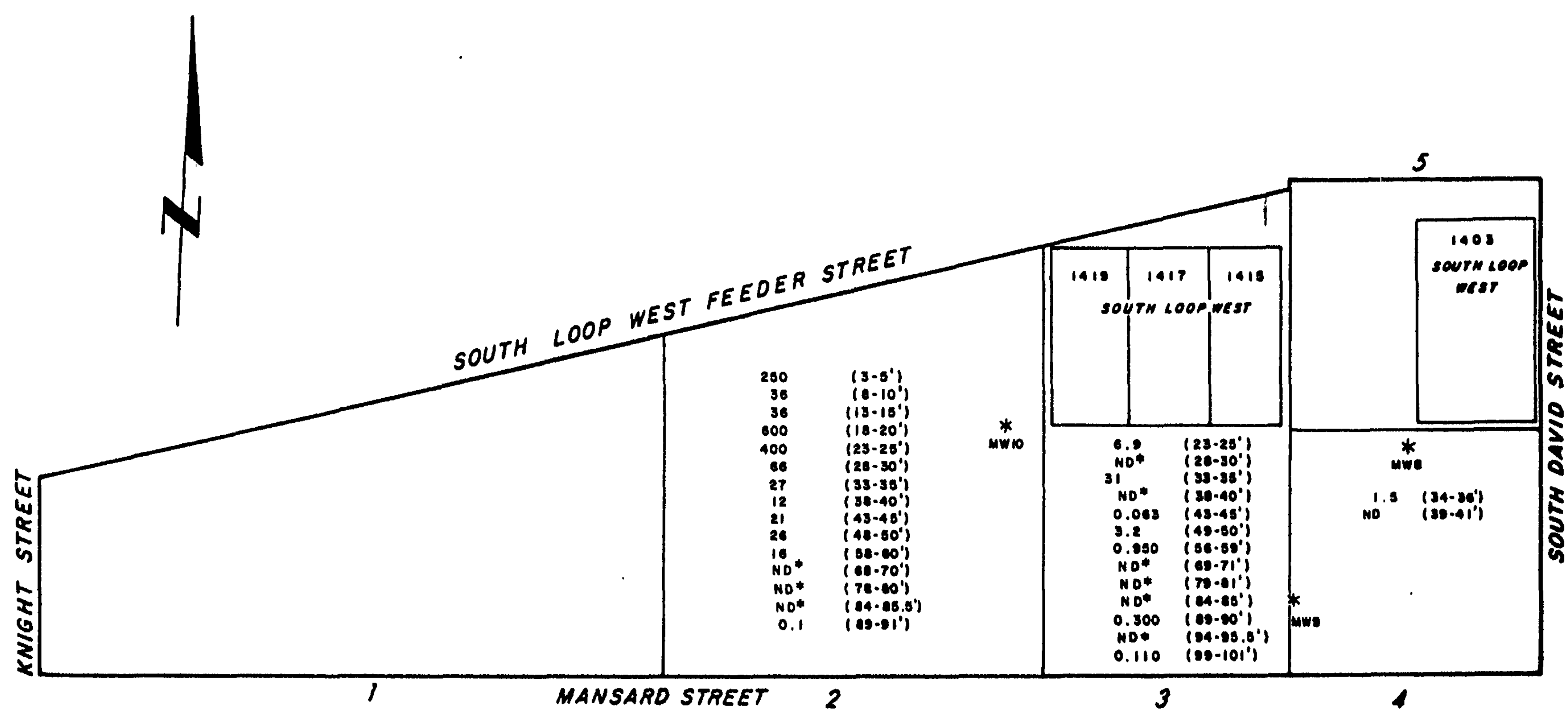


**FIGURE I**

**TCE VALUES FOR MONITOR WELL SOIL SAMPLES (PPM) PHASE II**

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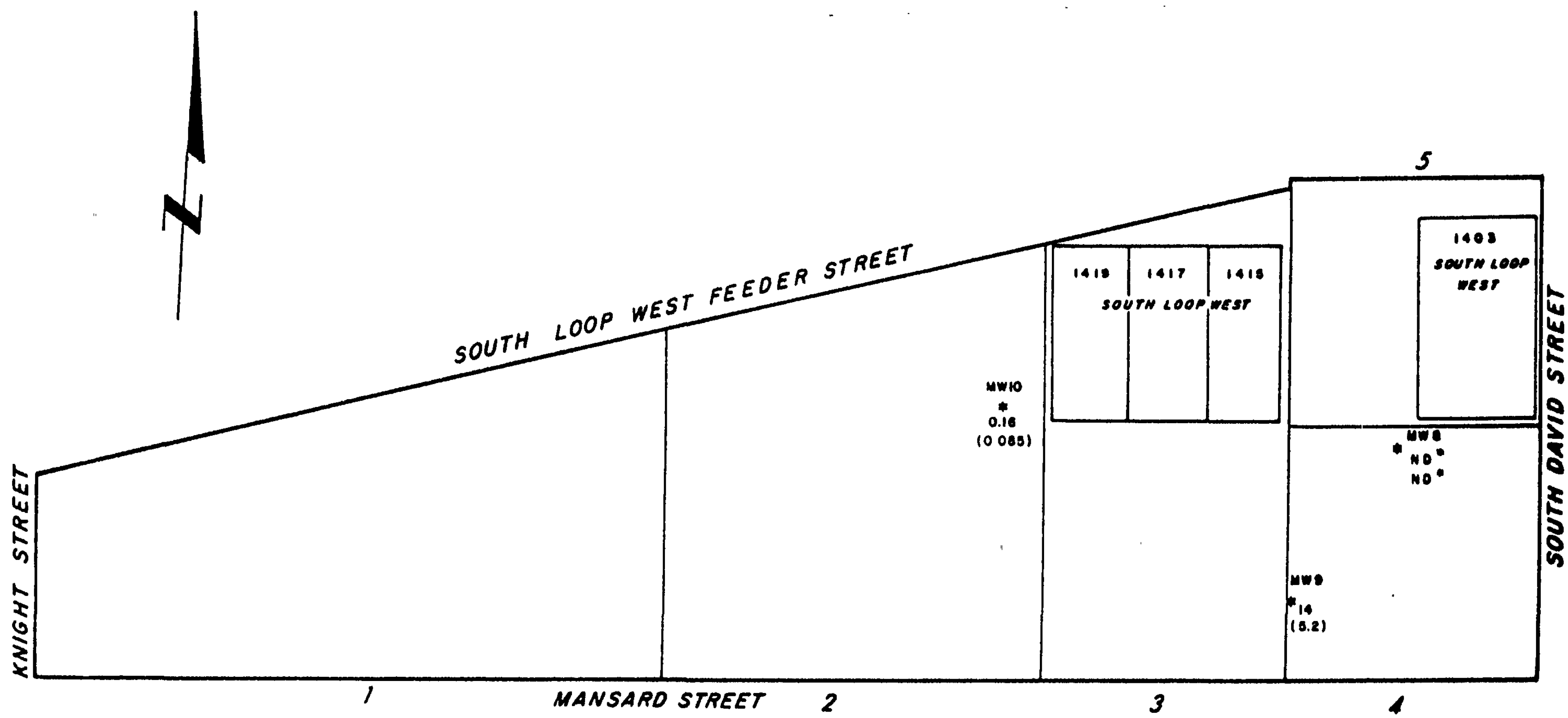
## LEGEND

| | |
|---|---|
| MW8 | MONITOR WELL NUMBER |
| * | MONITOR WELL LOCATION |
| 69(23-25') | SAMPLE VALUE; WITH DEPTH IN PARENTHESIS |
| ND | NOT DETECTED |
| ND* | NOT DETECTED; LESS THAN 0.04 PPM |




LEGEND

MW10 - MONITOR WELL NUMBER
* - MONITOR WELL LOCATION
0.160 - SAMPLE VALUE
ND* - NOT DETECTED ; LESS THAN 0.0021 PPM

FIGURE 2

TCE VALUES FOR INTERMEDIATE DEPTH (101 Feet) MONITOR WELL WATER SAMPLES (PPM).

(FIRST & SECOND ROUNDS)

0 5 15 25 35 45 100
SCALE IN FEET

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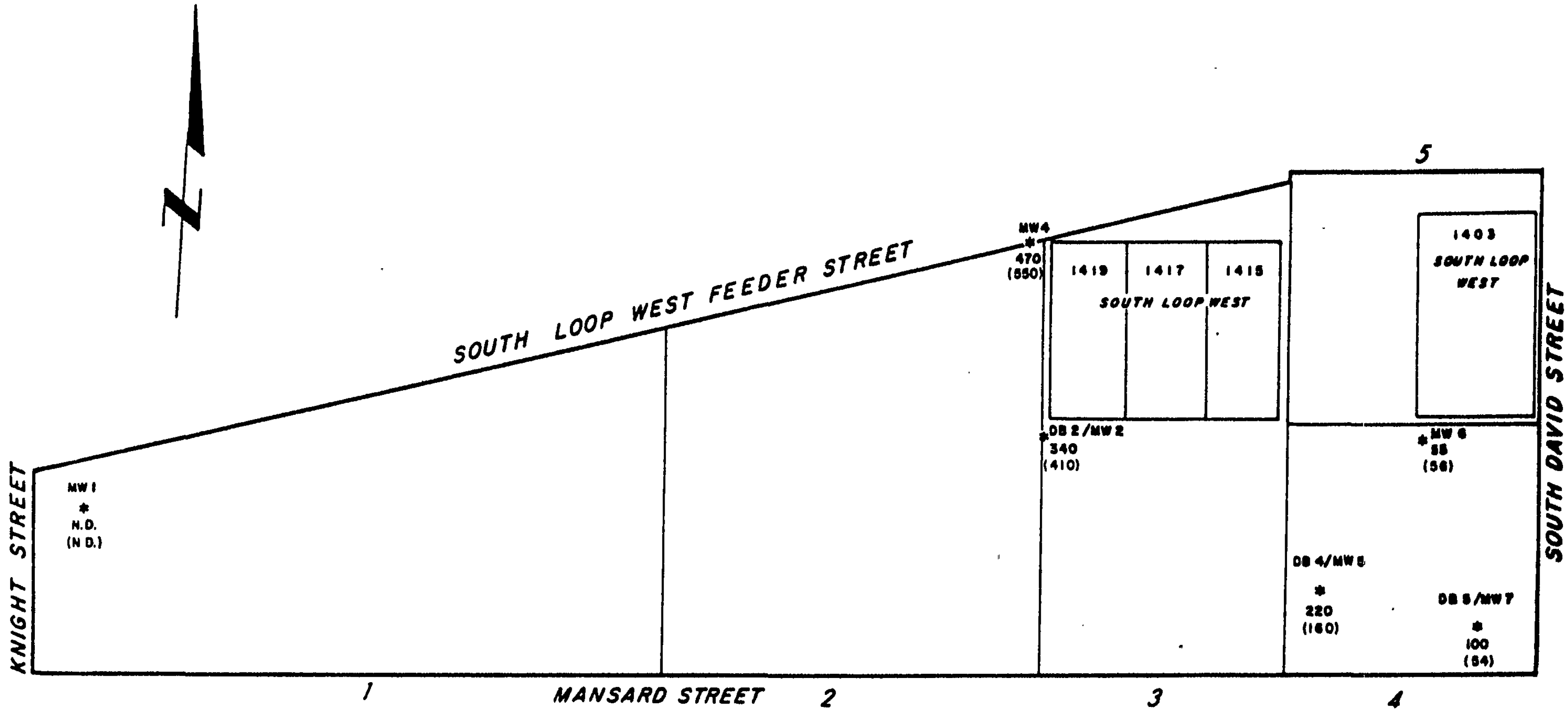


**LEGEND**

DB4/MW 5 – DEEP BORING/MONITOR WELL NUMBER
* – WELL LOCATION
220 – SAMPLE VALUE
N.D. – NONE DETECTED

**FIGURE 3**

TCE VALUES FOR SHALLOW DEPTH MONITOR WELL WATER SAMPLES (PPM).
(FIRST & SECOND ROUNDS) PHASE II

0 5 15 25 35 45 100
SCALE IN FEET

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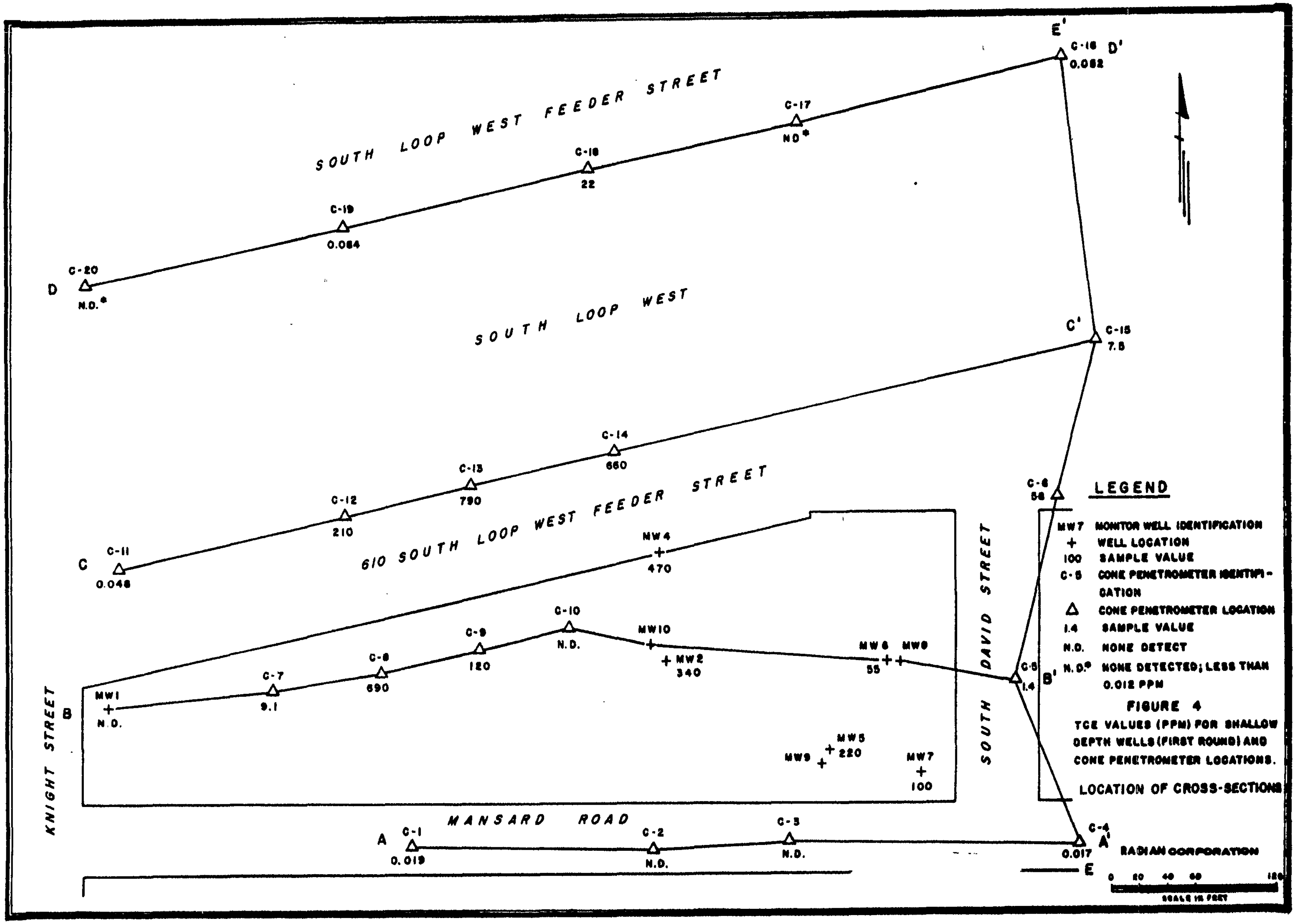


FIGURE 4
TCE VALUES (PPM) FOR SHALLOW DEPTH WELLS (FIRST ROUND) AND CONE PENETROMETER LOCATIONS.

Feasibility Study

Site conditions and cleanup limits were the major factors considered in reviewing the potentially applicable remedial technologies to remediate the groundwater and subsurface soils. This review generated a list of appropriate remedial technologies which were combined into eleven complete remedial packages, or alternatives, for remediating the groundwater and another three alternatives for remediating contaminated soils. Preliminary technical and cost evaluations of the fourteen total alternatives eliminated eight alternatives from further consideration, resulting in the selection of six remedial alternatives for a detailed analysis; however, the soil "No Action" alternative was combined with the groundwater "No Action" alternative, leaving five alternatives for the detailed analysis.

The final alternatives selected for the detailed analysis are:

Groundwater Alternative 1 - The "No Action" alternative means that no remedial activities other than monitoring will occur at the site.

Groundwater Alternative 2 - The collection and off-site deep well injection alternative includes removing the contaminated groundwater and transporting it off-site to a deep well injection facility where the water will be isolated in deep, impermeable geologic strata.

Groundwater Alternative 3 - The collection, on-site carbon adsorption, and discharge alternative encompasses collecting the contaminated groundwater, removing the contaminants with carbon, and discharging the treated water.

Groundwater Alternative 4 - The collection, on-site stripping, and discharge alternative includes removing the contaminated groundwater from the subsurface, volatilizing the TCE from the groundwater, cleaning the air emissions with a carbon column, and discharging the treated water.

Groundwater Alternative 10 - The collection, on-site catalytic dehydrochlorination, and discharge alternative encompasses chemically treating the contaminated water once it has been removed from the subsurface to remove both chlorine and hydrogen molecules. The resulting water is less hazardous and is then discharged.

Table 3 presents the final alternatives along with the screening criteria and screening results. The screening criteria consist of:

- Technical Analysis - the technical analysis screens each alternative based on its performance, reliability, implementability, an safety.
- Institutional Analysis - the institutional analysis screens each alternative based on its conformance with Applicable or Relevant and Appropriate Requirements (ARARs).
- Public Health Analysis - the public health analysis provides information on the degree to which each alternative protects public health, welfare, and the environment.
- Environmental Impacts Analysis - the environmental impacts analysis evaluated each alternative based on its beneficial and adverse environmental impacts.
- Cost Analysis - the cost includes detailed cost estimates and a cost sensitivity analysis.

The screening results are based on a rating system in which:

- "Low" denotes that the alternative does not meet the remedial objective;
- "Moderate" denotes that the alternative meets some or most of the remedial objectives; and
- "High" denotes that the alternative meets or exceeds the remedial objectives.

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TABLE 3
SUMMARY OF DETAILED EVALUATIONS FOR FINAL ALTERNATIVES

| Remedial Alternative | Technical Feasibility Analysis | Institutional Requirements Analysis | Public Health Analysis | Environmental Impacts Analysis | Total Present Worth |
|---|---|---|---|---|---|
| Groundwater | | | | | |
| 1. No Action | Low | Low | Low | Low | $ 364,015 |
| 2. Collection and Off-Site Deep Well Injection | Moderate | Moderate | High | Moderate | 4,409,905 |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | High | High | High | High | 1,063,154 |
| 4. Collection, On-Site Stripping, and Discharge | High | High | High | High | 654,537 |
| 10. Collection, On-Site Catalytic Dehydro-chlorination, and Discharge | Moderate | High | High | High | 5,877,460 |
| Discharge Options | | | | | |
| 1. Reinjection | High | High | N/A | High | $ 66,462 |
| 2. Discharge to POTW | High | High | N/A | High | 211,937 |

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## SECTION 1
## INTRODUCTION

Radian Corporation is under contract to the Texas Water Commission (TWC) to perform a Remedial Investigation/Feasibility Study (RI/FS) at the Industrial Transformer Superfund (ITS) site. A Remedial Investigation/Feasibility Study report (Radian, 1988) has been issued on the first phase of the RI/FS and a public hearing on that report has been conducted by the U.S. Environmental Protection Agency (EPA). That report and the subsequent public hearing focused on surface and shallow subsurface (0 to 4 feet) contamination. However, deeper contamination was discovered during the field investigation, and this report (Phase II) addresses that contamination.

Phase II of the RI investigated the magnitude and the extent of TCE contamination in deep subsurface soils and groundwater. This associated FS evaluates the technical, environmental and economic feasibility of the various cleanup alternatives that may be used at the site to remediate the TCE contamination of the groundwater and the subsurface soils. The EPA and TWC will then use this FS to recommend the cleanup alternative.

The objectives of the Remedial Investigation Phase II are to assess the nature, extent and magnitude of TCE contamination at the site, specifically in the deeper soil horizons and groundwater within the uppermost (approximately 30 feet deep) and intermediate (approximately 85 feet deep) water-bearing sands. The information generated in this Phase II RI is to be used in the Phase II FS to evaluate remedial action alternatives. Work conducted in both Phase I and Phase II has been financed through Cooperative Agreement No. V-0066416 between the EPA and the TWC. The RI/FS contract was executed June 30, 1986 and Amendment No. 1, which authorizes Phase II work at the site, was executed on October 28, 1987.

Both Phase I and Phase II RI/FS work at the ITS site is being performed as a CERCLA or Superfund project following evaluation by the Hazard





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Ranking System and inclusion on the National Priority List (NPL). CERCLA is an acronym for Comprehensive Environmental Response, Compensation and Liability Act, more popularly known as Superfund. It was enacted in 1980 to remediate hazardous substances at uncontrolled or abandoned hazardous waste sites and to provide funding and procedures for the federal government together with state governments to ensure remediation of hazardous substance locations, whether responsible party has been identified or not.

The Superfund Amendments and Reauthorization Act (SARA), a five-year extension of CERCLA, was signed into law October 17, 1986. SARA provides a number of additions to existing law but among the most important are:

- New emphasis is placed on risk reduction, using techniques that allow destruction/detoxification of waste, rather then preventing exposure. More pointedly, permanent solutions and treatments to permanently and significantly reduce the toxicity, mobility and/or volume of hazardous substances are preferred.

- Remediation must attain Federal applicable or relevant and appropriate requirements (ARARs) and more stringent State ARARs.

## 1.1 SITE DEFINITION

The Industrial Transformer Superfund site is located within the city limits of Houston, Texas. The specific lots and other contiguous lots within this block of land are bounded by Knight Street on the west, Mansard Street to the south, South David Street to the east, and the feeder road for I-610 South Loop West, to the north (Figure 1-1).

A detailed description is given in the Remedial Investigative Report (Radian, 1988), Section 1.1 Site Definition and Appendix A-1 Property Description.

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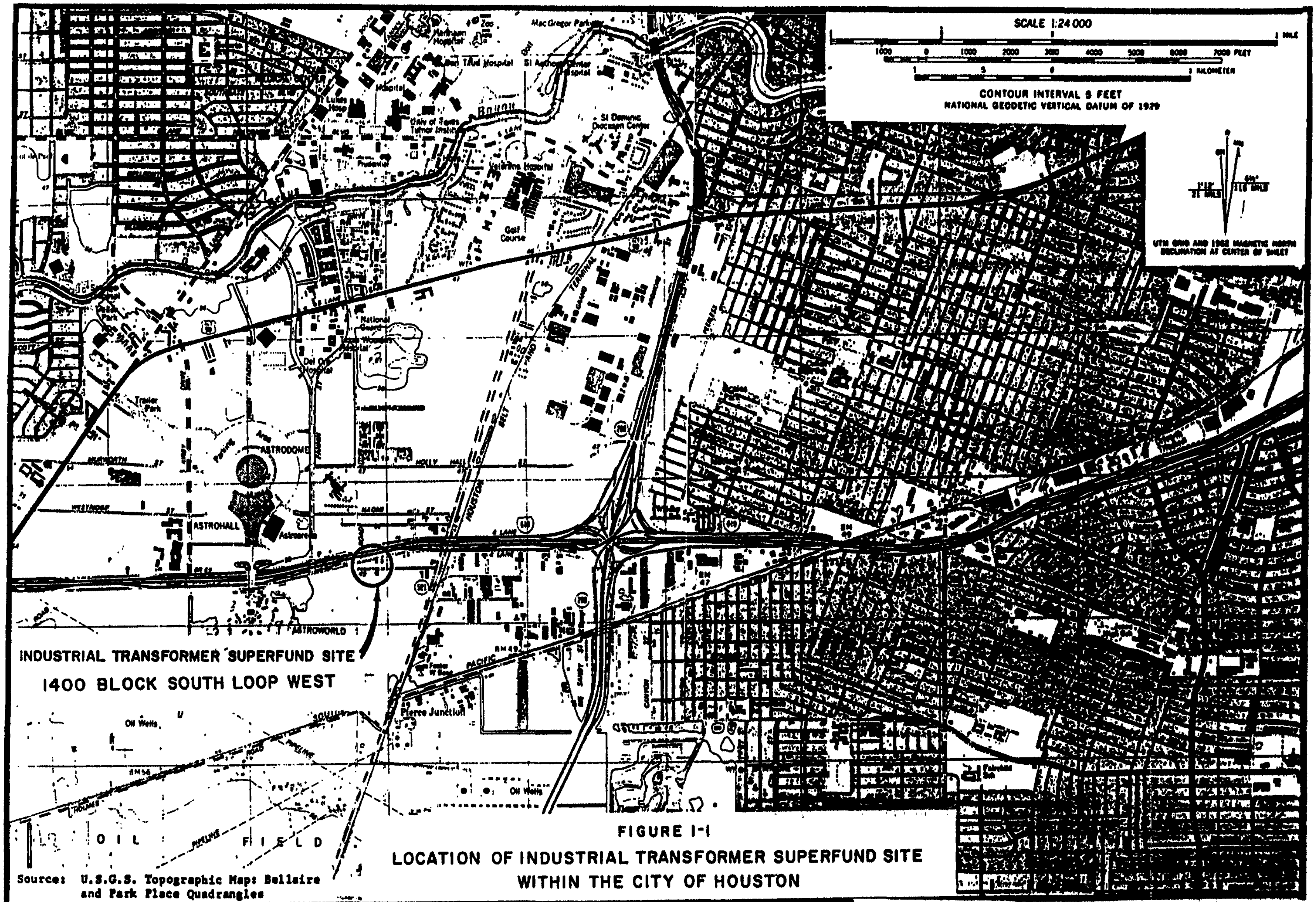


FIGURE I-1
LOCATION OF INDUSTRIAL TRANSFORMER SUPERFUND SITE
WITHIN THE CITY OF HOUSTON

Source: U.S.G.S. Topographic Map: Bellaire and Park Place Quadrangles

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## 1.2 SITE HISTORY

A detailed summary of the sequence of events surrounding the contamination at the ITS site is given in the Remedial Investigation Report (Radian, 1988a), Section 1.2 Site History.

As early as 1971, the Industrial Transformer Company, owned and operated by Mr. Sol Lynn, was located at 1415, 1417, and 1419 South Loop West in Houston, Texas. During the fall of that year, the first documented investigation of the site occurred when the City of Houston Water Pollution Control Division noted that workers of the Industrial Transformer Company poured oil out of electrical transformers onto the ground as they were dismantling the transformers. Oil and grease were observed lying on the soil and floating on standing water on-site and in the ditch adjacent to the property.

Further inspections yielded different results. An inspection of the ITS site on November 10, 1978 by a representative of the TWC showed no signs of oil spills or unauthorized discharges. Another representative of the TWC observed on January 13, 1980 old drums and an oily discharge from a drum storage area behind Sila-King, Inc., a chemical supply company operating at 1419 South Loop West. Samples collected by the City of Houston Department of Health on September 11, 1981 showed the major soil and water contaminant to be TCE. After City of Houston work crews noticed strong chemical vapors on November 14, 1981 while installing a water line along the north side of Mansard Road, representatives of the TWC and the City of Houston Department of Health investigated the site and noticed a strong TCE smell. The representatives also observed approximately 75 empty, punctured drums prominently labelled "trichloroethene" that were scattered across Mr. Lynn's property. These drums disappeared from the site between March 16 and March 29, 1982. Finally, the Solid Waste Enforcement Unit of the TWC requested in 1984 that the EPA rank the ITS site for corrective action through the Superfund program.





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## 1.3 STATEMENT OF THE PROBLEM

### 1.3.1 Results of Phase I Remedial Investigation

Conclusions made in the RI from Phase I work indicate that PCBs greater than the 25 ppm action limit set by the EPA were restricted to the uppermost two feet of soil. In the surface and shallow subsurface soils, TCE was found in concentrations less than 161 ppm, the criterion set by the EPA for Phase I surface soil cleanup. However, the TCE concentration in deeper soils and groundwater could not be conclusively defined.

A summary of TCE results from Phase I RI work (Figure 1-2) shows concentrations of 0.02 to 2 ppm TCE in surface soils that are mostly limited to Areas 3 and 4. Shallow soil borings (sampled at interval of 0 to 2 foot and 2 to 4 foot depth) were drilled at various locations. TCE concentrations in the borings ranged from 0.005 to 150 ppm, and the highest concentrations were limited to the upper two feet.

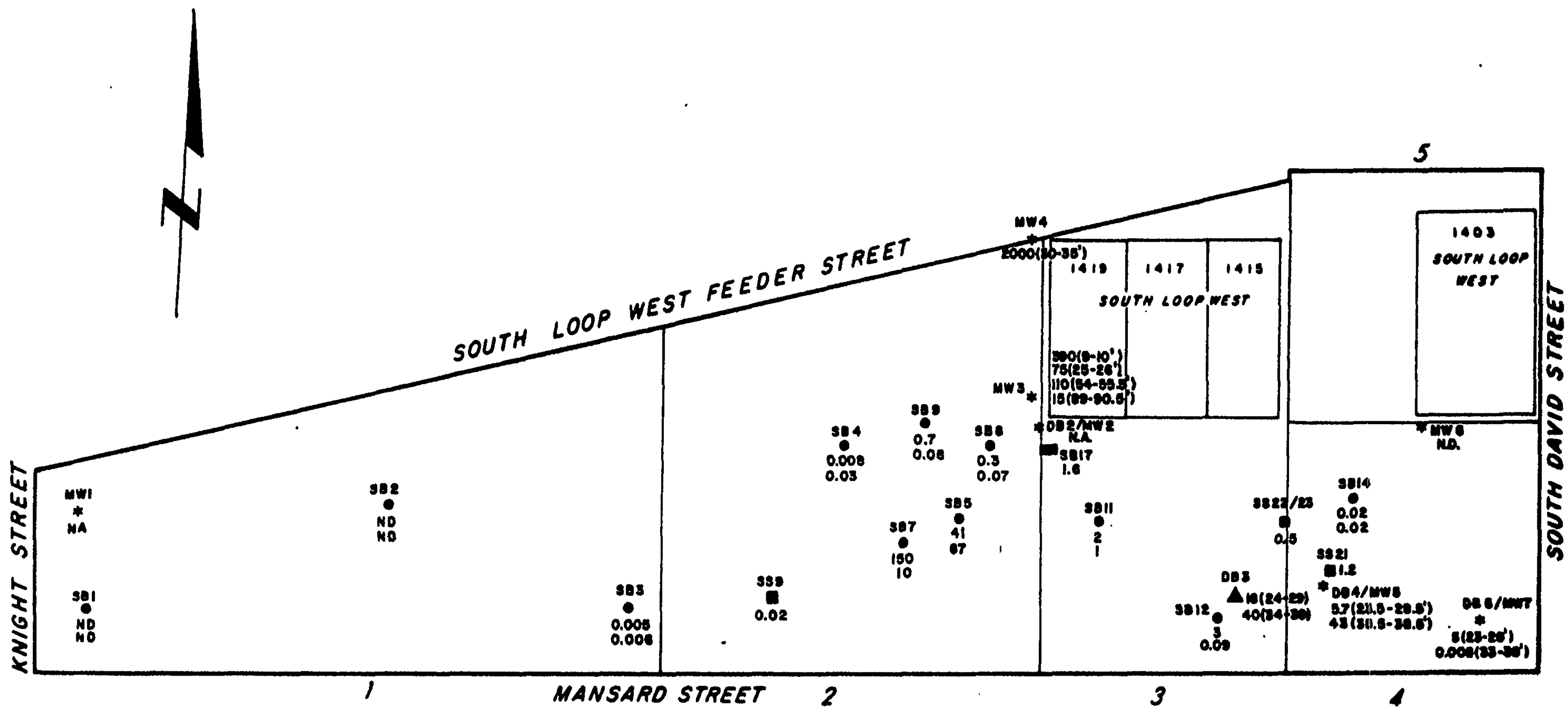
#### 1.3.1.1 Deep Soil Horizons Results - Phase I

Within those deep boreholes and monitor wells drilled during Phase I field activities, the highest TCE concentration values were found within MW-3, i.e. 390 ppm (9 to 10 foot depth), 75 ppm (25 to 26 foot depth), 110 ppm (54 to 55.5 foot depth) and 15 ppm (89 to 90.5 foot depth). MW-3 is located close to an old water well (now plugged and abandoned) that may have acted as a conduit for contaminated fluids to migrate through the subsurface.

#### 1.3.1.2 Water Sampling Results - Phase I

Two rounds of sampling water from the uppermost water-bearing zone were conducted in Phase I. Round 1 TCE distributions are illustrated in Figure 1-3 and Round 2 in Figure 1-4. Highest values were found in MW-2 (430 ppm/500 ppm, Rounds 1 and 2 respectively), followed by MW-4 (250 ppm/ 400 ppm), MW-5 (190 ppm/300 ppm), MW-7 (46 ppm/72 ppm), MW-6 (25ppm/26ppm) and lastly MW-1 (0.003 ppm and 0.0007 ppm).

I-6




LEGEND

| | | | |
|---|---|---|---|
| DB3 | DEEP BOREHOLE NUMBER | ND | NONE DETECTED |
| ▲ | BOREHOLE LOCATION | SS9 | SURFACE SOIL NUMBER |
| 18(24-29') | TCE CONCENTRATION (PPM); WITH DEPH IN PARENTHESIS | ■ | SAMPLE LOCATION |
| MW6 | MONITOR WELL NUMBER | 0.02 | TCE CONCENTRATION (PPM) |
| * | MONITOR WELL LOCATION | | |
| NA | NOT ANALYZED | | |
| SB11 | SHALLOW BOREHOLE NUMBER | | |
| ● | BOREHOLE LOCATION | | |

FIGURE I-2

SUMMARY OF TCE VALUES IN SOIL SAMPLES - PHASE I

0 5 15 25 35 45 100

SCALE IN FEET

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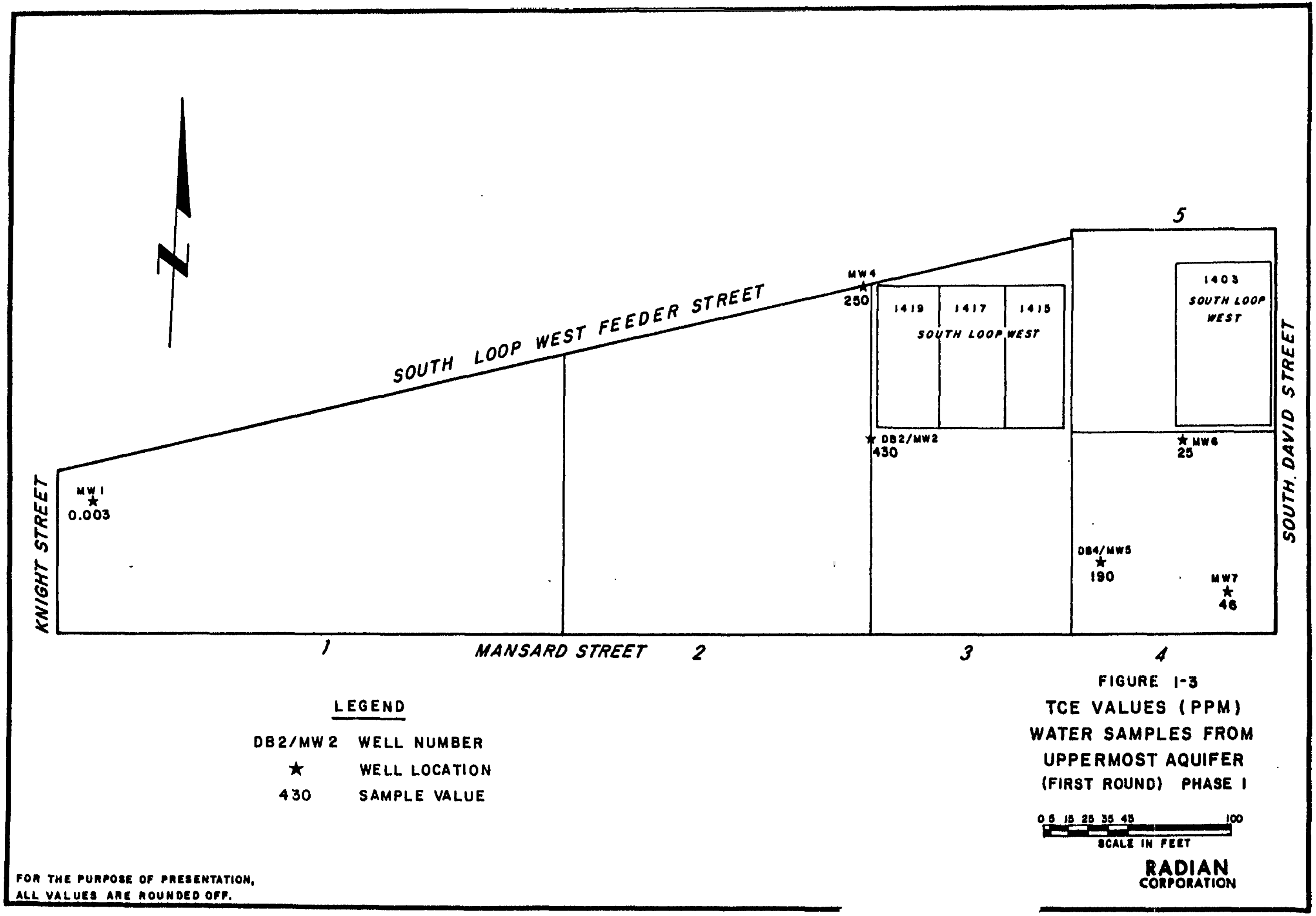


FIGURE 1-3
TCE VALUES (PPM)
WATER SAMPLES FROM
UPPERMOST AQUIFER
(FIRST ROUND) PHASE I

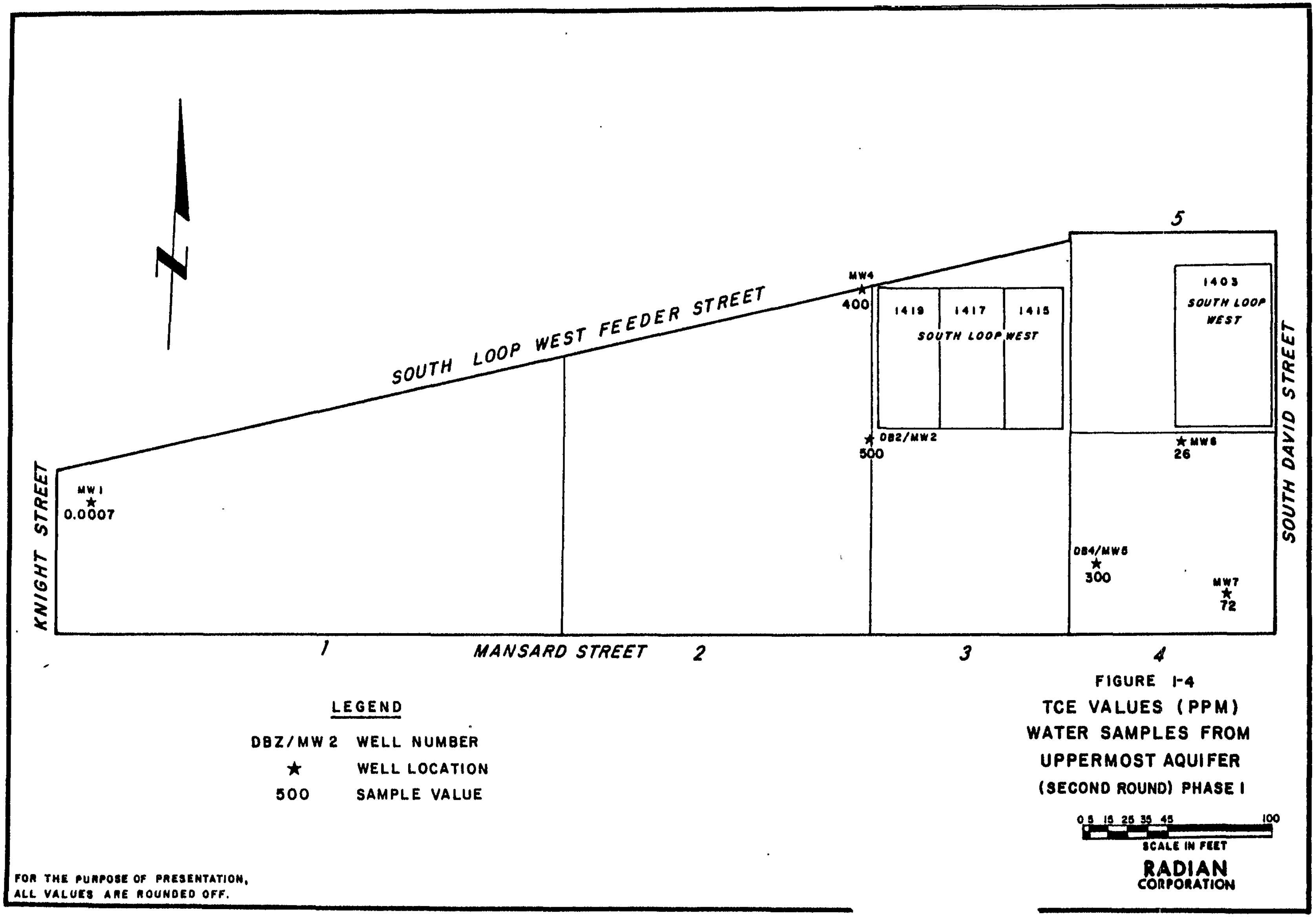


FIGURE I-4
TCE VALUES (PPM)
WATER SAMPLES FROM
UPPERMOST AQUIFER
(SECOND ROUND) PHASE I

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### 1.3.2 Results of Phase II Remedial Investigation

In Phase II work, the objectives were to assess the nature, extent and magnitude of TCE contamination in deeper soil horizons and the groundwater within the uppermost and intermediate water-bearing zones. In essence, Phase II was to determine the vertical extent and magnitude of TCE migration through the underlying clays and the lateral extent of a TCE plume in the uppermost and intermediate water-bearing sands.

#### 1.3.2.1 Deep Soil Horizons Results - Phase II

A summary of TCE findings in soil samples from the Phase II work shows that TCE is present in varying amounts throughout the three boreholes completed to below the intermediate water-bearing zone (Figure 1-5).

TCE was detected in soil samples from all three wells completed in the intermediate water-bearing zone. In MW-10, TCE is detected in soils from the surface to a depth of approximately 60 feet and at a depth of 89 to 91 feet, which includes the clay underlying the intermediate water-bearing zone. The highest values are located at 18 to 20 feet (600 ppm TCE) and 23 to 35 feet (400 ppm TCE). A value of 27 ppm is detected in the sediment from the uppermost water-bearing sand. In MW-9, TCE is detected at a depth of 23 feet down to 59 feet and at a depth of 89 to 90 feet and 99 to 101 feet, which includes the clay underlying the intermediate water-bearing zone. The high value (31 ppm) is located in the sediment of the uppermost water-bearing zone. In MW-8, a relatively smaller amount of TCE of 1.5 ppm was detected in the uppermost water-bearing zone at 34 to 36 feet depth.

In conclusion, this distribution indicates that TCE is present continuously to a depth of 60 feet and sporadically to a depth of 101 feet in MW-10. The significant TCE concentrations were observed in the slightly more permeable silty clay layers of 18 to 20 feet (600 ppm) and 23 to 25 feet (400 ppm). In MW-9, TCE is present continuously at depths of 23 to 59 feet and at 89 to 90 feet and 99 to 101 feet, indicating a possible lateral transport of TCE within slightly silty lenses and further vertical migration through





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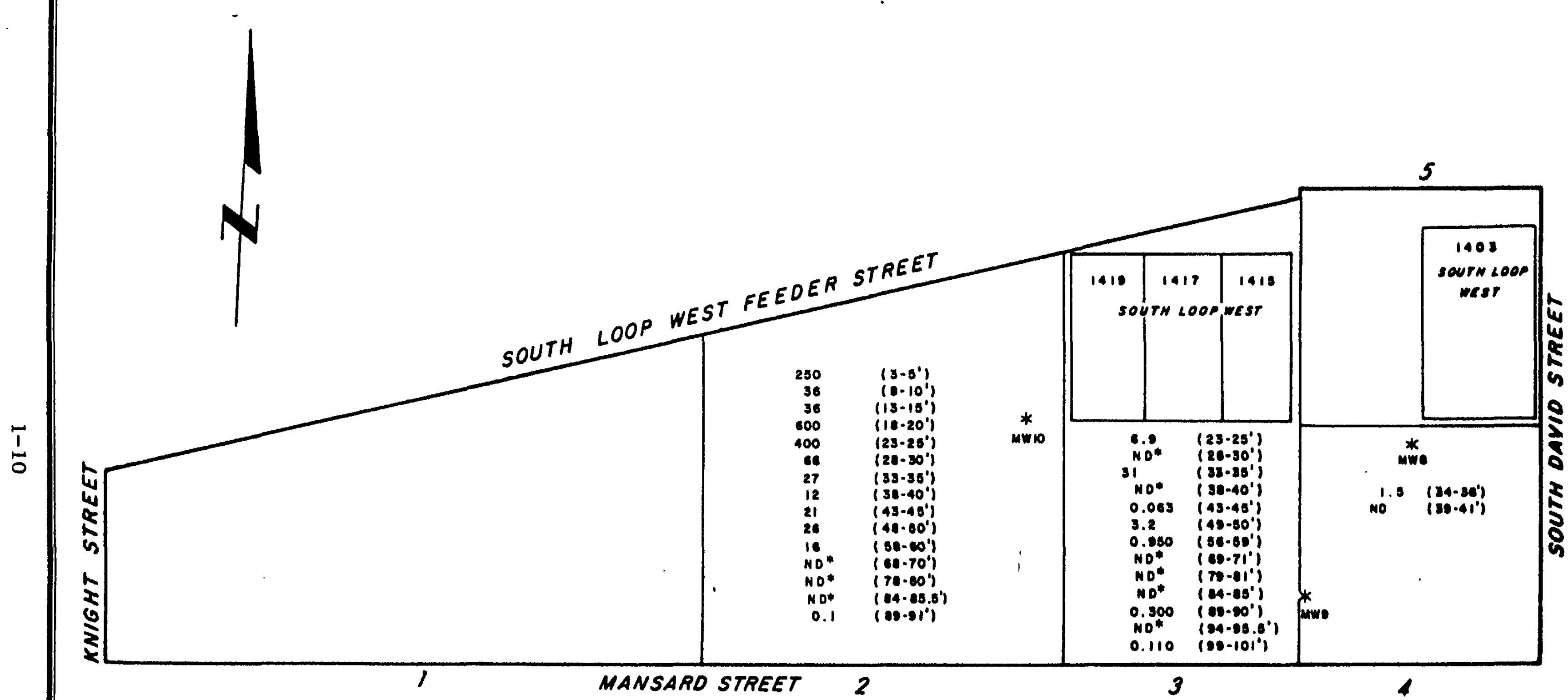


FIGURE 1-5

TCE VALUES FOR MONITOR WELL SOIL SAMPLES (PPM) PHASE II

## LEGEND

MW8 MONITOR WELL NUMBER

* MONITOR WELL LOCATION

69(23-25') SAMPLE VALUE; WITH DEPTH IN PARENTHESIS

ND NOT DETECTED

ND* NOT DETECTED; LESS THAN 0.04 PPM

0 5 15 25 35 45 100

SCALE IN FEET

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underlying clays. In MW-8, TCE is present only within the uppermost water-bearing sand, indicating that the presence of TCE at this location is due to lateral transport through the permeable, sandy, water-bearing zone.

#### 1.3.2.2 Water Sampling Results - Phase II

During Phase II activities, two rounds of groundwater samples were collected from the uppermost water-bearing sand. Round 1 and Round 2 distributions are illustrated in Figure 1-6. The highest TCE values were detected in the uppermost water-bearing zone. The highest values, 470 ppm/550 ppm, from Rounds 1 and 2 respectively, were detected in MW-4. This well is to the north of MW-2, where highest values of TCE were detected during Phase I groundwater sampling and is in an upgradient position from MW-4. The next highest values were detected in MW-2 (340 ppm/410 ppm), followed by MW-5 (220 ppm/160 ppm), MW-7 (100 ppm/54 ppm), MW-6 (55 ppm/56 ppm) and MW-1 (none detected).

Two rounds of water samples were collected from the intermediate water-bearing zone in Phase II (Figure 1-7). TCE was detected in all three wells, with highest values found in MW-9 (14 ppm/5.2 ppm, Rounds 1 and 2 respectively), followed by MW-10 (0.160 ppm/0.085 ppm) and lastly, MW-8 (0.0008 ppm/0.0005 ppm). The off-site extent of the plume of contamination is unknown but is assumed to be moving in the direction of groundwater flow, east-southeast.

#### 1.3.2.3 Cone Penetrometer Sampling Results - Phase II

A water-sampling penetrometer was used to log the formations and collect one round of water samples, both on-site and off-site. These locations were selected in order to define the extent and magnitude of the plume of contamination (Figure 1-8). The highest TCE value to be detected in any water sample, Phase I or II, was 790 ppm and was from an off-site penetrometer location to the north and northwest of reported high values at MW-4 and MW-2. These high values and distributions indicate that a TCE plume is moving with the direction of groundwater flow within the uppermost water-bearing sand. The





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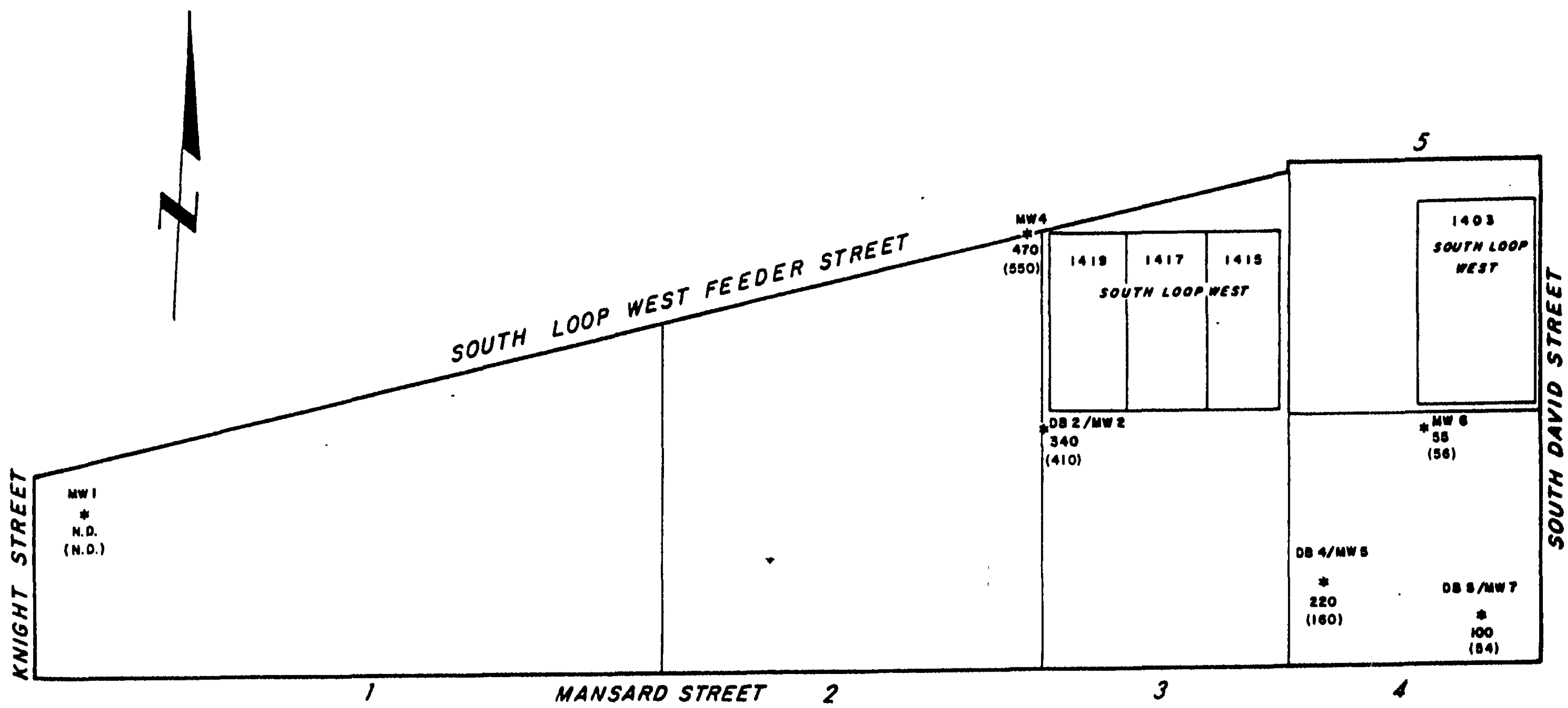


LEGEND

DB4/MW 5 – DEEP BORING/MONITOR WELL NUMBER

* – WELL LOCATION

220 – SAMPLE VALUE

N.D. – NONE DETECTED

FIGURE 1-6

TCE VALUES FOR SHALLOW DEPTH MONITOR WELL WATER SAMPLES (PPM).

(FIRST & SECOND ROUNDS) PHASE II

0 5 15 25 35 45 100

SCALE IN FEET

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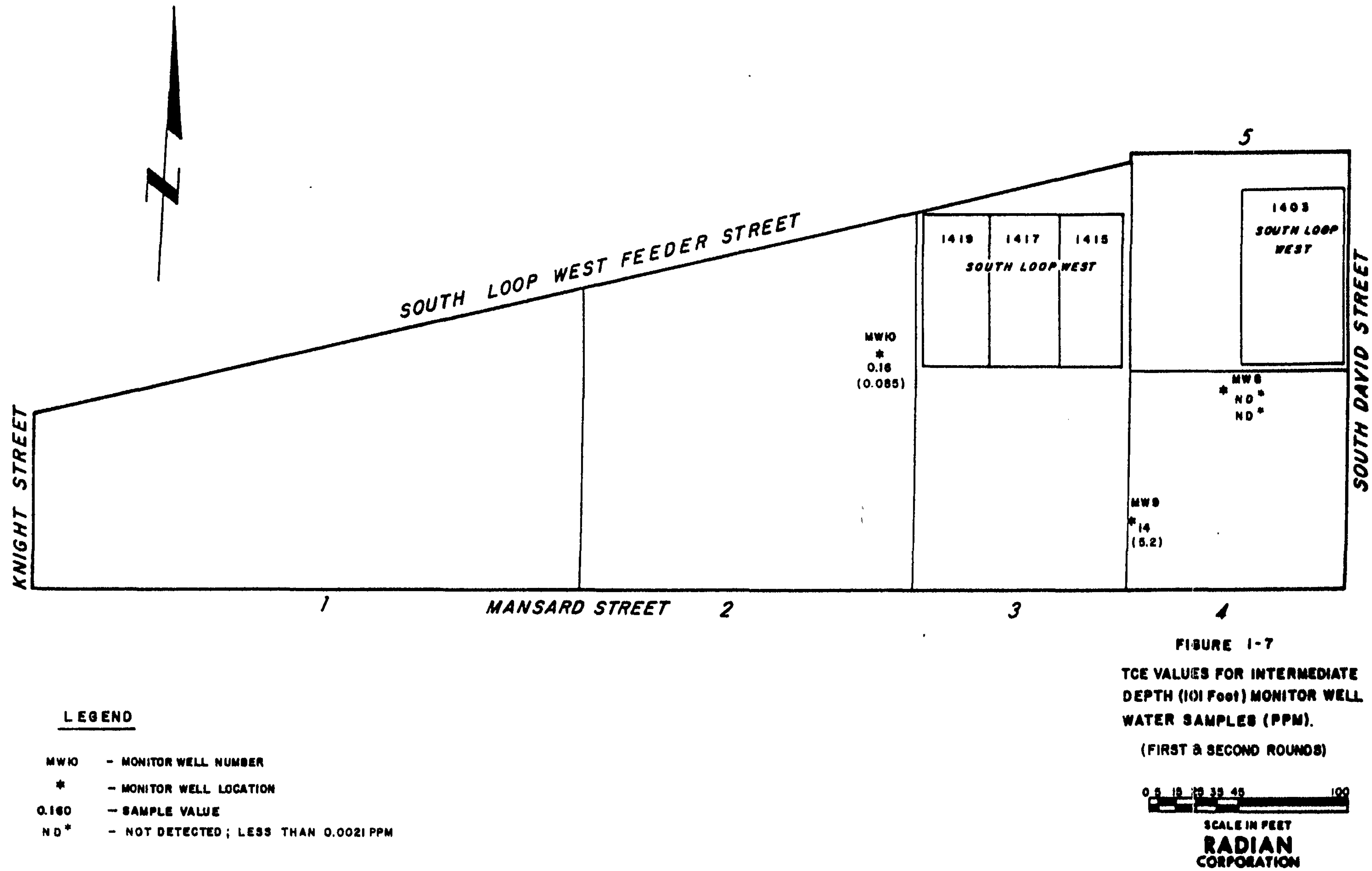


FIGURE 1-7

TCE VALUES FOR INTERMEDIATE DEPTH (101 Foot) MONITOR WELL WATER SAMPLES (PPM).

(FIRST & SECOND ROUNDS)

LEGEND

MW10 – MONITOR WELL NUMBER

* – MONITOR WELL LOCATION

0.160 – SAMPLE VALUE

ND* – NOT DETECTED; LESS THAN 0.0021 PPM





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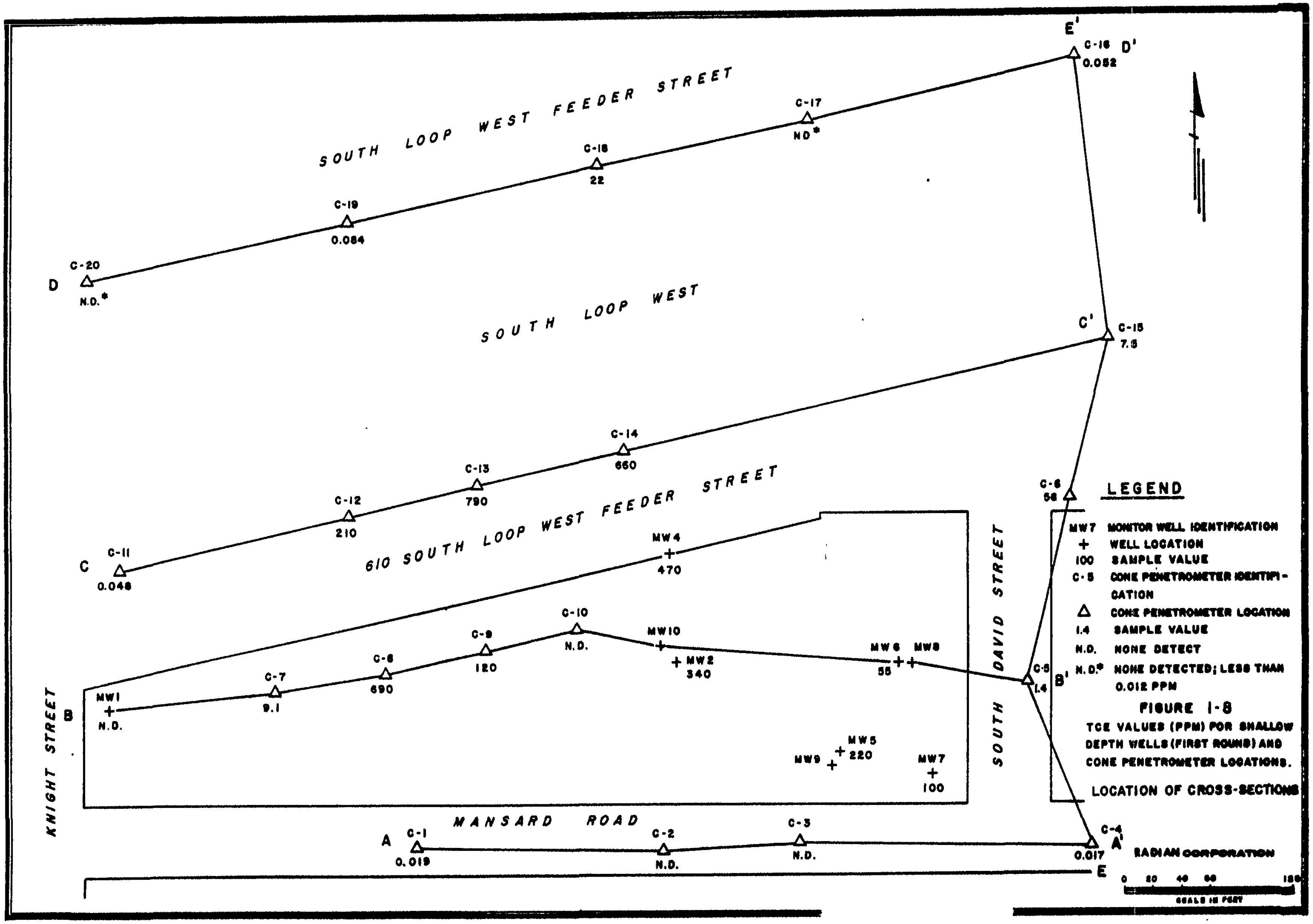


FIGURE 1-8
TCE VALUES (PPM) FOR SHALLOW DEPTH WELLS (FIRST ROUND) AND CONE PENETROMETER LOCATIONS.

series of off-site penetrometer locations along Mansard Road show TCE ranging from none detected to 0.019 ppm, indicating that the plume is present in the upgradient direction from possible sources on-site. Along South David Street, bordering the east side of the site, TCE concentrations ranged from 0.017 ppm to 58 ppm, indicating the plume edge extends an unknown distance further to the east.

As discussed above, the highest cone penetrometer concentrations were found along the north side of the site (to the south side of South Loop West). This series of penetrometer locations dissects the plume. Values range from 0.048 ppm (at the far west end of the series) to a high of 790 ppm and back to a low at 0.052 ppm TCE at the far east end of the series. Plume edges thus extend some unknown distance to the east and west beyond the sampled locations.

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The plume is also found on the far north side of South Loop West in concentrations ranging from 0.015 ppm to 22 ppm to 0.052 ppm TCE (from west to east). This distribution indicates that the plume is moving to the north of the site and extends some unknown distance to the north beyond the sampled locations.

#### 1.3.2.4 General Aquifer Parameter Results

Table 1-1 lists the Total Dissolved Solids (TDS), Carbonaceous Oxygen Demand (COD) and metals found in water samples from the uppermost and intermediate water-bearing zones.

Water from both water-bearing zones exceeds the recommended drinking water standards (500 mg/L) for TDS by two to four times.

A metals analysis for a sample from the uppermost water-bearing zone shows relatively small amounts of metals. These are within or are very close to recommended drinking water standards. An analysis of all constituents listed for the drinking water standards was not done. This data implies that water from these water-bearing zones could be treated and suitable for human consumption.

TABLE 1-1. GENERAL AQUIFER PARAMETERS

| Well | Aquifer | Parameter* | Result** |
|---|---|---|---|
| MW-1 | Upper | TDS | 3670 mg/L |
| MW-4 | Upper | TDS | 2320 mg/L |
| MW-7 | Upper | TDS | 2590 mg/L |
| MW-8 | Intermediate | TDS | 1040 mg/L |
| MW-9 | Intermediate | TDS | 1650 mg/L |
| MW-4 | Upper | COD | 110 mg/L |
| MW-4 | Upper | Silver | N.D. |
| | | Aluminum | 1.7 mg/L |
| | | Arsenic | N.D. |
| | | Boron | 0.9 mg/L *** |
| | | Barium | 0.065 mg/L |
| | | Beryllium | N.D. |
| | | Calcium | 180 mg/L |
| | | Cadmium | N.D. |
| | | Cobalt | N.D. |
| | | Chromium | 0.037 mg/L*** |
| | | Copper | N.D. |
| | | Iron | 0.83 mg/L |
| | | Potassium | N.D. |
| | | Magnesium | 100 |
| | | Manganese | 0.12 mg/L |
| | | Molybdenum | N.D. |
| | | Sodium | 440 mg/L |
| | | Nickel | 0.03 mg/L*** |
| | | Lead | N.D. |
| | | Antimony | N.D. |
| | | Selenium | N.D. |
| | | Silicon | 13 mg/L |
| | | Thallium | N.D. |
| | | Vanadium | N.D. |
| | | Zinc | 0.40 mg/L |

* TDS = Total Dissolved Solids
COD = Carbonaceous Oxygen Demand

** N.D. = Not Detected

*** Less than 5 times the detection limit.



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Hydraulic conductivity and transmissivity were determined for both water-bearing units. The hydraulic conductivity for the uppermost aquifer was determined to range from 0.63 to 2.0 feet/day. The thickness of that unit ranges from 4 to 5 feet to yield a transmissivity of 3.0 to 10 $feet^2$/day. The hydraulic conductivity for the intermediate aquifer ranges from 0.31 to 0.87 feet/day. Thickness of the intermediate unit ranges from 5 to 6.5 feet. Transmissivity ranges from 1.59 to 5.65 $feet^2$/day.

#### 1.3.2.5 Conclusions Regarding the Phase II Remedial Investigation

Chemical analyses and hydrogeologic testing have yielded the following conclusions about subsurface contamination at the ITS site:

- TCE contamination is observed continuously in the soils on-site from the surface to a depth of 60 feet and sporadically thereafter to a depth of 101 feet, the extent of this investigation.
- TCE contaminates both the uppermost and the intermediate water-bearing units. The highest concentrations (790 ppm) in the uppermost aquifer was observed off-site underneath the median strip between I-610 South Loop West and the southern feeder street. The volume of contaminated water in this zone is estimated to be 3.2 million gallons.
- Because of the southerly and westerly gradients observed in the intermediate aquifer, it appears that the Phase II investigation discovered the upgradient end of the plume in that unit. Thus, a volume of contaminated groundwater could not be calculated for that aquifer.
- The extent of the TCE plume in the uppermost aquifer to the north of I-610 and to the east of the site has not yet been defined.

## 1.4 CLEANUP CRITERION

The Phase I Remedial Investigation identified the significant pathways of exposure to TCE as ingestion (soil and groundwater) and inhalation. Soils containing greater than 161 ppm TCE were determined to be a possible health hazard due to direct ingestion or inhalation of the resulting vapors in a confined space (such as a ditch). However, no surface soil samples at the



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site contained more than 2 ppm TCE and the acute, short-term vapor exposure from TCE would not exceed the 50 ppm Threshold Limit Value set by the American Council of Government and Industrial Hygienists. Therefore, groundwater ingestion was the only pathway of TCE exposure to be investigated in Phase II.

A review of public health (toxicity, carcinogenicity, mutagenicity, teratogenicity) and environmental impacts (reactivity, persistence) is provided in the RI Phase I. The conclusion of this review is that the EPA has classified TCE as a probable human carcinogen. The EPA Water Quality Criterion for TCE has been set at zero for fish and drinking water. When zero is unobtainable, a criterion corresponding to a $10^{-6}$ cancer risk factor is allowed. For TCE this criterion is 2.7 ug/L. The 2.8 mg/L level has been identified by EPA (1986) as a reference concentration for TCE for carcinogenicity.

Under the Safe Drinking Water Act, health advisories describing nonregulatory concentrations of drinking water contaminants at which adverse health effects would not be expected to occur have been set for different exposure durations. In the health advisory dated March 31, 1987, suitable data were not available to estimate the one-day, ten-day, or longer-term health advisory for TCE.

The objective of potential remedial actions at the site is to minimize the potential for exposure to TCE-contaminated groundwater and to protect uncontaminated groundwater for current and future use. To meet this objective, the TWC and the EPA have established a groundwater cleanup criterion for the uppermost and intermediate water-bearing units equal to the MCL of 0.005 mg/L (5ppb). This cleanup criterion is not to preclude an evaluation of natural attenuation. In addition, the EPA and the TWC have determined that the MCL is an Applicable or Relevant and Appropriate Requirement (ARAR).

## 1.5 OBJECTIVES OF THE FS PHASE II

The objective of this FS is to examine remedial alternatives for TCE in groundwater (both uppermost and intermediate water-bearing units) and, by





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extension, the TCE present in the subsurface soils. As documented in the Phase II RI, TCE occurs in significant amounts at depth, both in the soil and in the groundwater. TCE is the principal contaminant at the site and is classified by the EPA as a potential carcinogen (Federal Register, November 13, 1985). This FS evaluates the various remedial technologies applicable to both water-bearing units and combines them into complete alternatives designed to remediate the TCE contamination. Applicable or Relevant and Appropriate Requirements (ARARs) will be used to determine the effectiveness of a remedial alternative to achieve both public health and environmental objectives.

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## SECTION 2
## PRELIMINARY SCREENING OF TECHNOLOGIES

As noted in Section 1, this FS deals with the remediation of groundwater from the uppermost and intermediate water-bearing units contaminated with TCE at the ITS site. In addition, subsurface soils are contaminated with TCE and may act as a continuing source of contamination for the aquifers. Thus, this section presents a description of available response actions and remedial technologies for both soil and groundwater, and then screens the technologies for applicability to the ITS site.

In developing the candidate list of remedial technologies, the first step was to identify the categories of responses which may be carried out to remediate TCE contaminated groundwater. Once the response categories were finalized, appropriate remedial technologies within the context of each response were identified.

Subsequently, the remedial technologies were screened according to the following criteria:

- Implementability;
- Time required for implementation;
- Proven effectiveness; and
- Applicability to site and waste.

First, a technology was evaluated for its physical implementability. Next, the length of time required to implement the remedial technology was considered. Implementation time can be estimated for most remedial technologies; however, some of the technologies that are not well proven or do not have sufficient site specific data may require an indeterminate amount of time for the desired amount of remediation to occur. Therefore, a pilot or treatability study may be required to better determine the time required for remediation. Third, the remedial technologies were screened for proven effectiveness. A



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successful pilot or field scale trial of a technology renders that technology as "proven effective." Finally, the determination of the applicability of the remedial technology to the site and waste refers to site conditions and contaminant properties. Based on these four screening criteria, a determination for further consideration as a remediation technique at the site was made.

The ability of the remedial technologies to remediate the contaminants to meet relevant public health or environmental standards, the cost of implementing the technology, and the ability of the technology to achieve permanent treatment or destruction of the wastes were not used as criteria for the elimination of a technology at this stage of the screening process. The criteria will be discussed in later sections of this FS.

## 2.1 GENERAL RESPONSE ACTIONS

The EPA guidance document (1985) lists general response actions which may be implemented to remediate the contaminated groundwater. Using information from the guidance document and based on site conditions and the nature of TCE, a list of generalized response actions has been developed and is shown in Table 2-1. This table also lists technologies that may be categorized within each general response.

The following sections provide additional details on the technologies identified in Table 2-1 and review them for applicability to the ITS site. For ease in presentation, subsequent discussions will be based on technologies rather than general response actions.

## 2.2 IDENTIFY AND SCREEN TECHNOLOGIES

Technologies to fulfill the general response actions listed on Table 2-1 are presented on Table 2-2. Also presented on Table 2-2 are the assessments for each technology for the four screening criteria. An assessment of the applicability to this site and the waste material present (TCE) is also given. Finally, a judgement as to the need to consider the technology further

TABLE 2-1

LIST OF GENERAL RESPONSE ACTIONS

| General Response Actions | Examples of Technology Types |
|---|---|
| No Action | Some monitoring and analyses. |
| Containment | Groundwater containment barrier walls. |
| Collection | Groundwater pumping; gas venting; gas collection systems. |
| Complete Removal | Excavation and removal. |
| On-site Treatment | Treatment of pumped groundwater on-site using technologies such as incineration, solidification, and chemical, physical, or biological methods. |
| Off-site Treatment | Pumping and transporting groundwater off-site for treatment using technologies such as incineration, solidification, and chemical, physical, or biological methods. |





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TABLE 2-1
LIST OF GENERAL RESPONSE ACTIONS
(Continued)

| General Response Actions | Examples of Technology Types |
|---|---|
| In Situ Treatment | In place treatment of contaminated soils using technologies such as biodegradation. |
| Storage | Use of temporary storage structures. |
| On-site Disposal | Land application. |
| Off-site Disposal | Land application; deep well injection. |
| Alternative Water Supply | Municipal water system; deeper or upgradient wells; individual treatment devices. |
| Relocation | Relocate residents temporarily or permanently. |

Source: U.S. EPA, 1985

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TABLE 2-2
SCREENING OF REMEDIAL TECHNOLOGIES
FOR CONTAMINATED GROUNDWATER

| REMEDIAL TECHNOLOGIES | SCREENING CRITERIA Implementable | Acceptable Amount of Time Required | Effectiveness Proven | Applicable to Site and Waste | Warrants Further Consideration | Comments |
|---|---|---|---|---|---|---|
| NO ACTION | Yes | Yes | No | Yes | Yes | Used for comparison purposes. |
| CONTAINMENT BARRIERS | | | | | | |
| Slurry wall/trench | No | Yes | Yes | Yes | No | Access a problem; does not prevent vertical migration; support technology only. |
| Grout curtains(injection) | No | Yes | No | No | No | Does not work well in clay soils. |
| Steel sheet piling | No | Yes | No | No | No | Does not create a positive seal. |
| Vibrating beam | No | Yes | No | No | No | Does not work well in clay soils. |
| COLLECTION (GROUNDWATER) | | | | | | |
| Recovery wells | Yes | Yes | Yes | Yes | Yes | Used in conjunction with some type |
| Trenches | No | Yes | Yes | Yes | No | of disposal or treatment method. |
| French drains | No | Yes | Yes | No | No | Access problems. |
| Tile drains | No | Yes | Yes | No | No | Access problems. |
| Pipe drains | No | Yes | Yes | No | No | Access problems. |
| COLLECTION (VOLATILE GASSES) | | | | | | |
| Passive pipe vents | Yes | Yes | Yes | No | No | Used in conjunction with some type |
| Passive trench vents | Yes | Yes | Yes | No | No | of disposal or treatment method; |
| Active gas collection | Yes | Yes | Yes | No | No | not applicable because of clay soils at ITS. |
| EXCAVATION AND REMOVAL | | | | | | |
| Backhoe | No | Yes | Yes | No | No | Not a feasible cleanup method for contaminated groundwater. |
| Cranes and Attachments | No | Yes | Yes | No | No | Excessive depth of excavation for soil removal. |
| Front end loaders | No | Yes | Yes | No | No | |
| Scrapers | No | Yes | Yes | No | No | |

TABLE 2-2
SCREENING OF REMEDIAL TECHNOLOGIES
FOR CONTAMINATED GROUNDWATER
(Continued)

| REMEDIAL TECHNOLOGIES | SCREENING CRITERIA: Implementable | SCREENING CRITERIA: Acceptable Amount of Time Required | SCREENING CRITERIA: Effectiveness Proven | Applicable to Site and Waste | Warrants Further Consideration | Comments |
|---|---|---|---|---|---|---|
| SOLIDIFICATION | | | | | | |
| Thermoplastic, organic polymer | Yes | Yes | No | No | No | Greatly increases volume of contaminated materials; many |
| Cement | Yes | Yes | No | No | No | agents are not effective with |
| Lime | Yes | Yes | No | No | No | organic compounds. |
| Fly Ash | Yes | Yes | No | No | No | |
| DISPOSAL/STORAGE AND DISCHARGE (On-site and Off-site) | | | | | | |
| Landfills | Yes | Yes | No | No | No | Requires water to be solidified. |
| Surface impoundments | Yes | Yes | No | No | No | Involves volatilization & evaporation. |
| Land application | No | Yes | Yes | No | No | Not proven for TCE. |
| Deep well injection | Yes | Yes | Yes | Yes | Yes | Readily available near the ITS site. |
| Temporary storage | Yes | Yes | Yes | Yes | Yes | Temporary measure; support technology only |
| Discharge to storm sewer | Yes | Yes | No | Yes | Yes | Support technology only. |
| Discharge to POTW | Yes | Yes | No | Yes | Yes | Requires approval of City and TWC. |
| Reinjection | Yes | Yes | Yes | Yes | Yes | Support technology only. |
| INCINERATION (On-site and Off-site) | | | | | | |
| Liquid injection | Yes | Yes | Yes | No | No | Not practical with low heat value of wastes. |
| PHYSICAL TREATMENT (On-site only) | | | | | | |
| -Carbon adsorption | Yes | Yes | Yes | Yes | Yes | Spent carbon will require treatment. |
| -Stripping | Yes | Yes | Yes | Yes | Yes | May release volatile compounds into air; steam or air may be used. |
| -Evaporation | Yes | No | Yes | Yes | No | Releases organic compounds in the air through volatilization. |
| -Reverse osmosis | Yes | Yes | Yes | Yes | Yes | Produces concentrated waste stream. |
| -Liquid-liquid extraction | Yes | Yes | No | Yes | No | Does not produce a waste stream that can be directly discharged; not proven |
| -Distillation | No | Yes | Yes | Yes | No | Extremely energy-intensive process. |
| -Precipitation, flocculation, sedimentation | Yes | Yes | Yes | Yes | Yes | May be used to remove suspended & dissolved solids; support technology only. |
| -Soil Washing | Yes | Yes | Yes | Yes | Yes | Utilizes a solvent or water. |



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TABLE 2-2
SCREENING OF REMEDIAL TECHNOLOGIES
FOR CONTAMINATED GROUNDWATER
(Continued)

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| REMEDIAL TECHNOLOGIES | SCREENING CRITERIA Implementable | Acceptable Amount of Time Required | Effectiveness Proven | Applicable to Site and Waste | Warrants Further Consideration | Comments |
|---|---|---|---|---|---|---|
| CHEMICAL TREATMENT (On-site only) | | | | | | |
| Calcination | Yes | Yes | No | Yes | No | Thermal destruction method; not proven. |
| Chlorinolysis | Yes | Yes | Yes | Yes | Yes | Resource recovery method that produces carbon tetrachloride from wastes. |
| Hydrolysis | Yes | Yes | Yes | Yes | Yes | Destroys chlorinated hydrocarbons; products maybe as or more toxic than parent compounds. |
| Microwave discharge/plasma | Yes | Yes | No | Yes | No | Innovative; not proven effective. |
| Ozonolysis | Yes | Yes | No | Yes | Yes | Oxidation of contaminants with ozone; enhances effectiveness of activated carbon. |
| Photolysis | Yes | Yes | No | Yes | Yes | Innovative; support technology to enhance ozonolysis. |
| Wet Air Oxidation | Yes | Yes | Yes | Yes | Yes | Innovative; may be catalyzed. |
| Catalytic Dehydrochlorination | Yes | Yes | Yes | Yes | Yes | Innovative. |
| Super Critical Water | ? | ? | No | ? | No | Unproven technology. |
| BIOLOGICAL TREATMENT (On-site and Off-site) | | | | | | |
| Activated sludge | Yes | Yes | Yes | No | No | Innovative in treatment of hazardous waste. |
| Anaerobic digestion | Yes | Yes | Yes | No | No | Microbes extremely sensitive to chlorinated hydrocarbons; innovative. |
| Trickling filters | Yes | Yes | Yes | No | No | Low organics removal efficiency; innovative. |
| Aerated lagoons | Yes | Yes | Yes | No | No | Allows for volatilization to occur. |
| IN SITU TREATMENT | | | | | | |
| Biological | Yes | ? | No | Yes | No | Utilizes methane & oxygen to stimulate subsurface microbes. |
| Stripping | Yes | Yes | No | Yes | No | Air collection and treatment system must also be utilized; not proven. |
| Stabilization/solidification | Yes | Yes | No | Yes | No | Not proven for long term disposal of high-level organics. |
| NON-TREATMENT TECHNOLOGIES | | | | | | |
| Alternative water supply | Yes | Yes | No | No | No | Lack of positive remedial action; may result in contamination of deeper aquifers. |
| Relocation of residents | No | No | No | No | No | Does not address contamination of deeper aquifers. |

and general comments about the technology are given. A discussion of each technology and the "no action" alternative are given below.

### 2.2.1 No Action

The "no action" general response action will encompass some monitorin, and analyses. This particular response and its associated technologies are included as a baseline to which the other remedial methods are compared.

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### 2.2.2 Containment Barriers

Groundwater containment barriers are structures built below grade that control groundwater by impeding lateral flow. Groundwater containment barriers include injecting grout through boreholes or driving piling to create a barrier that is impermeable to groundwater in the lateral direction. Containment barriers also include slurry walls which are constructed by excavating a trench through the saturated zone to an impermeable strata. The trench is excavated through a slurry mixture of bentonite and water which forms the barrier. Containment barriers provide no treatment, but contain the contaminated materials so they may later be treated or disposed using an additional remedial technology.

As shown in Table 2-2, a variety of groundwater containment barriers are available and proven. However, none of the containment barriers is applicable to the conditions at the ITS site for a variety of reasons. First, extending containment facilities to the impermeable strata below the intermediate aquifer (about 100 feet) is not readily implementable. Second, containment barriers do not slow or prevent vertical migration of contaminants. Furthermore, the bulk of the contamination in the uppermost aquifer lies under I-610. Containment barriers may not be placed across or through the highway without impeding traffic flow. Land use near the area may also prevent the installation of containment barriers. However, this technology may be useful to surround the plume on the upgradient side during a pump and treat scheme to prevent the pumping of excessive amounts of uncontaminated water; thus, this technology may be further considered as a support technology.

In specific terms, various containment barriers are screened from further consideration. Grout curtains and vibrating beams do not work well clay soils. Steel sheet piling does not create a positive seal to contain groundwater.

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### 2.2.3 Collection (Groundwater)

Collection of a contaminant plume may be accomplished through the use of a system of pumping wells or drains properly located around the plume. These methods can prevent further transport of dissolved contaminants as well as extract the contaminated groundwater for disposal or treatment. The efficiency of a collection system depends on the hydraulic conductivity of the aquifers and the solubility of the contaminant. Subsurface drains usually consist of perforated pipes or tiles laid in gravel-filled trenches. In all cases, these methods collect contaminated groundwater and transport it above ground for treatment or disposal with an additional remedial technology.

As shown in Table 2-2, several types of collection systems are available and have been proven effective. Recovery wells used in conjunction with pumps to remove contaminated groundwater from the subsurface for additional treatment are a proven method of aquifer restoration, are applicable to the ITS site, and will be considered further. Subsurface drains and trenches may be implementable for collecting groundwater from the shallow water-bearing unit; however, because of the depth of the intermediate water-bearing unit and access constraints proposed by I-610, installing drains to collect groundwater for remediation would not be feasible. Therefore, subsurface drains will no longer be considered.

### 2.2.4 Collection (Volatile Gases)

Collection of volatile gases through soil venting removes contamination from the vadose zone. Soil venting through pipe vents or trenches removes the gases trapped in the pore spaces and from shallow groundwater. These gas may then be treated or released.

Several methods of both passive and active soil venting are listed in Table 2-2 and have been proven effective for treatment of TCE contamination. However, the predominantly clay nature of the soils at the site make this technology inapplicable. Thus, this technology type will no longer be considered.

### 2.2.5 Excavation and Removal

Excavation and removal is an additional method for treating contaminated soils and preventing leaching of contaminants into the groundwater. As with soil venting, this method does not treat contaminated soils or groundwater. Instead, this method involves the removal of the contaminated materials for additional treatment or disposal with another remedial technology.

Table 2-2 lists several methods for excavation and removal. However, considering the depth to contamination, the large amounts of soils and water that will require excavation and constrained access due to I-610, this method is not feasible and will not be considered further.

### 2.2.6 Solidification/Stabilization

Solidification methods involve mixing the contaminated soils and groundwater with a physical or chemical binding agent. The mixture is then cured to a solid form which may be easily handled for further treatment or disposal. Most solidification methods require at least partial drying of the soils and, therefore, are not applicable to groundwater. Solidification increases the volume of contaminated material which needs to be disposed of or treated further. Many methods of solidification are not applicable to





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organics, some clays, and/or volatile compounds; and the long term effectiveness of solidification/stabilization has not been proven. Furthermore, materials to be solidified must be excavated first. Since excavation is not applicable, neither is solidification. Thus, solidification techniques will not be considered further.

### 2.2.7 Disposal/Storage and Discharge - (On-Site)

Land disposal, storage, and discharge are acceptable methods of handling wastes contaminated with TCE, provided regulations specifying acceptable concentrations are met. The off-site version of the disposal, storage, and discharge technologies will generally not be feasible at this site because of the large volume of water that would be require transport and the length of time over which transport would be required to remediate the groundwater.

The various disposal, storage, and discharge technologies offer varying degrees of treatment, which will be discussed below.

#### 2.2.7.1 Landfills

Landfills offer immobilization of contaminants for as long as the lining materials remain intact. Disposal of contaminated groundwater in a commercial landfill on or off-site would require solidification. Adequate space does not exist on-site for the construction of a landfill, as determined in the previous FS. The off-site landfill is not feasible for the following reasons:

- Solidification of the large amount of groundwater would be expensive and time-consuming;
- The waste volume would greatly increase due to the solidification; and
- The volume and time frame to implement this alternative are not conducive to off-site transport.

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Therefore, landfilling will not be considered further.

2.2.7.2 Surface Impoundments

Surface impoundments offer some measure of evaporation and volatilization (and possibly photolysis, which will be discussed in a later section of the report). Surface impoundments also offer temporary storage of water. Because the amount of treatment offered is not proven, and there is not available room on-site, surface impoundments will not be considered further.

2.2.7.3 Land Application

Land application requires large amounts of land which is not available at the site. Furthermore, this technology has not been proven for the treatment of TCE and may result in recontamination of the uppermost water-bearing unit as the water percolates downward. Therefore, land application will not be considered further.

2.2.7.4 Deep Well Injection

Deep well injection provides isolation of wastes and has been widely used for the disposal of aqueous wastes. Waste stream analyses and approval of the facility are required prior to using this technology. There are injection wells in the general area of the site; therefore, even though it means off-site transport of large volumes of water, this alternative will receive additional consideration.

2.2.7.5 Temporary Storage

Temporary storage does not result in treatment of waste and will be considered as a support technology only.





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#### 2.2.7.6 Reinjection

Reinjection of treated waters into the water-bearing unit will be considered only as a support technology to provide disposal of treated water. Reinjection has the added benefit of increasing the capture rate of the contaminant plume (Satkin, 1987).

#### 2.2.7.7 Discharge to Storm Sewer

This technology, used in conjunction with some type of pumping or collection technology, will consist of directly discharging the contaminated groundwater to a storm sewer. This technology does not provide for treatment or disposal of TCE and will not be considered as a stand-alone technology.

However, discharge to the storm sewer may be implemented once the groundwater has been treated using an additional technology. Periodic sampling and laboratory analyses of the groundwater would be required to ensure that the effluent stream meets the requirements of an NPDES permit.

#### 2.2.7.8 Discharge to POTW

This technology is also used in conjunction with a pumping or collection technology and consists of discharging the contaminated groundwater to a publicly owned treatment works (POTW) via the sanitary sewer system. Discharging to a POTW requires:

- An application to the City including a fee, a discharge location with legal description, and volume of discharge;
- A statement containing a lab analysis of the waste and a rate of discharge; and
- A letter from the TWC granting permission for such a discharge to occur.

The POTW treats wastes by employing a biological process. TCE has not been shown to consistently biodegrade under these circumstances and may



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pass through the plant untreated. Even so, this alternative warrants further consideration.

2.2.8 Incineration (On and Off-site)

Both on and off-site incinerators are available to treat the contaminated groundwater by providing thermal destruction of the TCE. Contaminated liquids may be injected into a variety of incinerator types where the high temperatures destroy the TCE to carbon dioxide ($CO_2$), water ($H_2O$), and hydrochloric acid (HCl).

However, incineration is not applicable to the aqueous stream that would result from withdrawing groundwater at the ITS site. Incineration will not be self-sufficient because of the low heat value contained in the contaminated groundwater and would require the addition of an impractical amount of additional fuel. Therefore, incineration is not implementable and will not be considered further.

2.2.9 Physical Treatment (On-Site)

A variety of methods are available to physically remove the TCE from the groundwater once it has been withdrawn using wells, trenches, or drains. The physical methods include both traditional and innovative treatment technologies. (Off-site treatment technologies are not feasible due to the large volume of groundwater that would require transport.)

2.2.9.1 Carbon Adsorption

The use of carbon adsorption to remove contaminants from groundwater has long been a favored remedial action because of its proven performance with volatile organics. However, a high suspended solids content will interfere with treatment effectiveness. This method may proceed using mobile or permanent carbon columns. Furthermore, carbon adsorption may be used in conjunction



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with an additional treatment or destruction technology to provide polishing prior to discharge of the water. Carbon adsorption will require disposal or regeneration of the spent carbon. Because this method offers reliable, treatment for groundwater contaminated with TCE, the technology will be considered in greater detail.

#### 2.2.9.2 Stripping

The stripping process removes volatile contaminants, such as TCE, from water by passing air or steam through the waste stream. Both types of stripping (air or steam) are capable of removing volatile organics efficiently In fact, greater than 99% removal efficiency has been achieved for TCE in groundwater (U.S.EPA,1983). Potential air pollution problems exist with stripping but may be mitigated with emission control devices. Therefore, stripping will be considered further.

#### 2.2.9.3 Evaporation

Evaporation is a passive form of stripping in which the contaminated water is allowed to sit in an evaporation chamber or pond until the contaminants volatilize through the actions of wind and solar energy. However, this method yields a much lower removal efficiency than stripping, thereby requiring unacceptable amounts of time for treatment, and evaporation does not allow for easily implementable air emissions controls. Therefore, this technology will not be considered further.

#### 2.2.9.4 Reverse Osmosis

Reverse osmosis is an expensive process used to remove contaminants (including volatile organics, metals, cyanides, and phenols) from an aqueous phase by passing the waste stream through a semi-permeable membrane under high pressure. The high pressure concentrates the wastes behind the membrane while clean water passes through the membrane, which must be cleaned or replaced often, depending on flow through the system. The concentrated waste stream must then be treated or disposed using an additional remedial technology. Because high solids concentrations will clog the membrane and impede its operation, pretreatment including settling of the waste stream may be required to protect membrane operation. Even so, this conventional technology will be considered in more detail.

#### 2.2.9.5 Liquid-Liquid Extraction

This technology utilizes a solvent to extract the TCE from the waste stream. The method has traditionally been used to extract contaminants from water samples for laboratory analyses, but an application to hazardous waste remediation exists. Liquid-liquid extraction concentrates the contaminants into the extracting solvent, creating a concentrated waste stream that must be further treated or disposed. Because the effectiveness of this technology is not proven, it will be screened from further consideration.

#### 2.2.9.6 Distillation

Distillation, used in the fractionation of petroleum products, is the process of boiling an aqueous solution and condensing the vapors to separate the various contaminants from the aqueous phase. Distillation is also used to purify organic chemicals and recover organic solvents. This energy-intensive technology results in high cleanup costs. Because this method is excessively energy intensive, it will be screened from further consideration.

#### 2.2.9.7 Precipitation, Flocculation, Sedimentation

Precipitation, flocculation, and sedimentation are processes for removing suspended solids from an aqueous solution. Precipitation occurs when a constituent held in solution passes out of the solution into solid form, usually through the actions of a precipitating agent, and the precipitate may then be physically removed. Flocculation is the process in which slow stirring of a coagulated wastewater will cause the solids to aggregate and form a rapidly settling floc, which may be then removed. Sedimentation uses gravity to remove suspended solids from wastewater. These three physical treatment methods will not greatly affect TCE concentrations, but they may be used to remove suspended solids prior to discharge or as a pretreatment method (e.g., for reverse osmosis). Therefore, these processes will only be considered further as support technologies.

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#### 2.2.9.8 Soil Washing

Soil washing is a method of flushing contaminated soils with water or solvent to collect contaminants that may then be collected in a trench or well system for additional treatment or disposal. This process will be considered further as a method to remove contamination from the subsurface soils.

### 2.2.10 Chemical Treatment (On-Site)

There are a variety of chemical treatment technologies capable of removing TCE from solution. These methods require that the groundwater first be removed from the subsurface before treatment may begin. They are discussed below.

#### 2.2.10.1 Calcination

Calcination is a process of thermally destroying volatiles and achieving a large reduction in the volume of waste with high organic concentrations. This technology has been used by the petroleum industry to treat tars and heavy residues and to produce solids from liquid radioactive wastes that may then be easily stored. However, this technology has not been proven effective in the treatment of TCE and will be screened from further consideration.

2.2.10.2 Chlorinolysis

Chlorinolysis is more of a manufacturing than treatment process which converts the chlorinated organics in waste streams to carbon tetrachloride. The reaction occurs with the addition of chlorine to the contaminated groundwater under conditions of high pressure and low temperature or low pressure high temperature. Other products of the reaction include hydrogen chloride (HCl) (Sworzyn and Ackerman, 1981). This technology is innovative and will be considered further.

2.2.10.3 Hydrolysis

Hydrolysis utilizes a water-induced cleavage to produce a double decomposition of chlorinated hydrocarbons often to organic acids and alcohols; however, the end products may be as or more toxic than the parent compounds (Brown, et al., 1980). Even so, this innovative technology warrants further consideration.

2.2.10.4 Microwave Discharge/Plasma

This innovative technology developed by Lockheed is capable of destroying organic and inorganic waste constituents, including TCE. The proprietary method destroys organic and inorganic waste constituents yielding carbon dioxide ($CO_2$) and water ($H_2O$). Potential products of the process include carbon monoxide (CO) and organochlorines (Sworzyn and Ackerman, 1981). Because this technology has not been proven effective for treating TCE wastes, it will not be considered further.

2.2.10.5 Ozonolysis

Ozonolysis, a type of chemical oxidation, employs ozone to oxidize and achieve destruction of the organics in waste streams. This technology has the potential to remove organic constituents in wastewater streams that are resistant to biological treatment. In addition, ozonolysis may be used instead of or as a supplement to carbon adsorption for the removal of TCE. This





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innovative process shows promise in treating the TCE-contaminated groundwater, and it will be considered in more detail.

#### 2.2.10.6 Photolysis

Photolysis utilizes ultraviolet (UV) light to break chemical bonds chlorinated organics. Photolysis is often used to improve the oxidation of organic compounds by combining its use with ozonolysis. Therefore, this technology will be further considered as a support technology to be used to enhance ozonolysis.

#### 2.2.10.7 Wet Air Oxidation

Wet air oxidation is a type of destruction method that occurs in the presence of high temperatures and pressures. Catalysts may be added to promote reaction rates at lower temperatures and pressures. The oxidation process uses oxygen to destroy organics to $CO_2$, $H_2O$, and HCl. Volatile organics may escape the process, but may be treated by conventional air pollution control techniques. This method is often employed to treat wastes that do not contain ample heat capacity to sustain incineration but are too concentrated for biological and other treatment methods. This method will be considered further to remediate the TCE contamination at ITS.

#### 2.2.10.8 Catalytic Dehydrochlorination

Catalytic dehydrochlorination (similar to the chemical dechlorination method discussed in Radian, 1988b) removes chlorine and hydrogen molecules from chlorinated hydrocarbons by reacting the chlorinated hydrocarbons with a dehydrochlorination agent such as sodium or potassium hydroxide mixed with polyethylene glycol. The end products of the reaction are a chloride salt, water, and an elimination product. While the potential disadvantages of this technology include the production of waste gases, organics, and a brine that may require further treatment or disposal, dehydrochlorination includes the



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following advantages: potential cost and energy savings and possible materials recovery (Harden and Ramsay, 1986).

Because this innovative technology appears to be applicable to the site and the waste, catalytic dehydrochlorination will be further considered.

2.2.10.9 Super Critical Water

The supercritical water process provides high temperatures and pressures to oxidize and destroy dilute aqueous materials. This energy intensive process yields hydrogen and carbon dioxide as some of the products. While one researcher mentioned in Helling and Lester (1986) has demonstrated greater then 99.99% destruction of volatile organics, supercritical water remains an unproven process for treating contaminated groundwater. Thus, this technology is screened from further consideration.

2.2.11 Biological Treatment (On and Off-Site)

Biological treatment methods may be used to destroy various organic compounds, with different compounds showing varying degrees of biodegradability depending on factors such as:

- Soluble organic compounds are generally more readily biodegraded than insoluble materials (solubility of TCE = 1100 mg/L @ 20$^{o}$C); and

- Key functional groups at certain locations on the contaminant molecules can result in assisting or hindering biodegradability. Specifically, halogenation appears to make various hydrocarbons more resistant to biodegradation (DeRenzo, 1980).

Biodegradation occurs as microorganisms consume the hydrocarbons as a food source either in the presence of oxygen (aerobic biodegradation) or in the presence of an environment without oxygen (anaerobic biodegradation).

However, laboratory experiments performed by Bouwer, et al. (1981) using TCE at concentrations commonly found in groundwater contamination scenarios showed that TCE did not biodegrade under aerobic or anaerobic conditions. Various biological methods may be used to degrade organic wastes, as shown in Table 2-3. Table 2-4 shows the products of the biological degradation pathway of TCE under ideal conditions. Note that the anaerobic pathway ends in the compound vinyl chloride. Vinyl chloride is less biodegradable, more soluble, and more toxic than TCE. Production of these intermediate and end products have been observed in strictly controlled environments.

Because available literature does not show the biodegradation of TCE to occur readily in either an aerobic or anaerobic setting, biological treatment technologies will no longer be considered.

TABLE 2-3

VARIOUS BIOLOGICAL REMEDIAL TECHNOLOGIES

| Technology | Environmental Conditions |
| --- | --- |
| Activated Sludge | Aerobic |
| Anaerobic Digestion | Anaerobic |
| Trickling Filters | Aerobic |
| Aerated Lagoons | Aerobic |





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TABLE 2-4

PREDICTED PRODUCTS OF BIODEGRADATION

Aerobic Biodegradation (Source: Fogel, et al., 1987)

Parent Compound: TCE

Intermediate Compounds: chlorinated epoxides
various chlorinated and non-chlorinated compounds; including dichloracetic acid, glyoxylic acid, and formic acid

End Products: $CO_2$ and biomass

Anaerobic Biodegradation (Source: Wood, *et al.*, 1985)

Parent Compound: TCE

Intermediate Compounds: cis 1,2-dichloroethene, trans 1,2-dichloroethene, 1,1-dichloroethene → Vinyl Chloride

### 2.2.12 In Situ Treatment

In situ treatment involves treating contaminated groundwater in place. The advantage of in situ treatment is the savings in time and money by treating in place instead of removing the contaminated fluids, treating and then disposing them in a manner acceptable to regulatory agencies.

#### 2.2.12.1 In Situ Biological Treatment

Contrary to the findings of Bouwer, et al. (1981) discussed previously, in situ biological remediation of aquifers contaminated with TCE has been observed by Semprini, et al. (1988). These researchers injected a semi-confined aquifer with pulses of methane and dissolved oxygen (DO) for use as nutrients and a continuous stream of a bromide tracer and TCE. Sampling occurred using an automated data acquisition system driven by a microcomputer. The first signs of biotransformation were seen at an observation well approximately 200 hours after injection of TCE. Mass balance calculations show the TCE degraded to some extent. Ratios of TCE breakthroughs relative to the bromide ion breakthroughs indicate a maximum degree of degradation of 30%.

If Semprini, et al. are correct and in situ biodegradation of TCE does occur, a 30% maximum degree of biodegradation would not be effective in remediating contaminated groundwater at this site to a level at which human health and the environment would no longer be adversely affected. Also, as discussed previously, the intermediate products of the biodegradation are not necessarily less harmful than the parent TCE. Thus, in situ biological treatment warrants no further consideration for the remediation of groundwater contaminated with TCE.

#### 2.2.12.2 In Situ Stripping

At least one vendor offers an in situ technique that uses overlapping augers to inject hot air and steam into the subsurface to strip volatiles.





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However, this technique has not yet been tested or proven effective and will no longer be considered.

2.2.12.3 In Situ Stabilization/Solidification

At least one vendor also offers an in situ process for stabilizing TCE wastes. Implementation of the process consists of drilling to the desired depth with the overlapping augers and injecting a special chemical grout to fix the wastes. An additive, sodium silicate, hardens the grout within 30 minutes. However, this method has not been field tested or proven effective in stabilizing TCE wastes. In addition, stabilization has not been proven effective for long term disposal of high level organics. Therefore, this technology will no longer be considered.



2.2.13 Non-Treatment Technologies

Various other technologies are available to address TCE contamination in groundwater that do not involve treatment or remediation. These technologies will be discussed and evaluated below.

2.2.13.1 Alternate Water Supply

Use of an alternative water supply for those persons whose wells may tap the contaminated aquifer at the ITS site is a possible remediation scheme. This method would result in supplying buildings that tap the shallow aquifers with an alternate water source - either deeper private wells or the municipal water supply. However, this type of remedial action does not address the cleanup objectives of minimizing the potential for exposure to TCE and protecting uncontaminated groundwater for current and future use. Therefore, this alternative is not considered an effective remedial measure and will no longer be considered.

### 2.2.13.2 Relocation of Residents

Relocation of residents is a measure that protects nearby residents from the health hazards imposed by the TCE contamination at the ITS site but does not address harm caused to the environment and does not halt the movement of the TCE to prevent contamination of additional water supplies. In addition, the EPA and the TWC are striving to allow continuation of current business and industrial activities on and near the site, and relocation of the residents would not meet this goal. Furthermore, relocation would require an unacceptable amount of time for implementation. For these reasons, relocation will no longer be considered as a remedial strategy for this site.

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# SECTION 3
# ALTERNATIVES DEVELOPMENT

Alternatives appropriate for the remediation of TCE contamination of the groundwater and subsurface soils were developed by assembling complimentary technologies into complete treatment packages. In this section, a comprehensive list of alternatives for both the groundwater and subsurface soils is described. From this list, the remedial alternatives were further screened to select alternatives to undergo detailed evaluation in a later section. The preliminary screening criteria for the remedial alternatives include:

- Public health and environmental quality impacts and protectiveness; and
- Administrative implementability and technical feasibility.

These screening criteria will be discussed in more detail later in this section.

Both the National Contingency Plan (NCP) and Superfund Amendments and Reauthorization Act (SARA) of 1986 emphasize the consideration of other applicable federal and state laws when implementing remedial alternatives at a Superfund site. In addition, the SARA amendments emphasize that remedial treatments permanently and significantly reduce the mobility, toxicity, and volume of hazardous materials to the maximum extent practicable (Section 121 (b) (1)). The EPA guidance document also specifies new requirements for remedial alternatives to be considered at a site.

## 3.1 COMBINATION OF APPLICABLE TECHNOLOGIES INTO PRELIMINARY REMEDIAL ALTERNATIVES

For the most part, technologies must be assembled together into remedial alternatives to provide comprehensive remediation of a site. These alternatives must address at a minimum:

1) A "no action" alternative,

2) A containment option involving little or no treatment, and

3) Various treatment alternatives including those incorporating innovative technologies.

Remedial alternatives for each of the above categories were developed using the remedial technologies previously examined and then evaluated. The preliminary alternatives for groundwater remediation are listed in Table 3-1

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## 3.2 DESCRIPTION OF PRELIMINARY GROUNDWATER ALTERNATIVES

The following alternatives pertain to remediation of the groundwater contaminated with TCE in both the uppermost and intermediate aquifers. Figure 3-1 outlines the plume area used to determine the volume of contaminated water requiring treatment from the uppermost water-bearing unit. Water from the intermediate water-bearing unit will also require remediation; however, the amount of water to be remediated from that unit could not be quantified. All groundwater remedial alternatives except no action and collection of volatile gasses (venting) require the collection of groundwater for additional treatment. The alternatives are discussed in more detail below.

### 3.2.1 Groundwater Alternative 1 - No Action

For this alternative, no new or additional remedial activities will be conducted at the site. However, long-term activities, including water sampling, are associated with this alternative to monitor the contamination.

This alternative does not address public health or environmental concerns. "No Action" does not comply with ARARs. Since this remedial alternative does not permanently or significantly reduce the mobility, toxicity, or volume of the TCE in the groundwater, this alternative also violates the SARA recommendations. With this alternative the TCE remains in the groundwater, and the public health threat from ingestion of contaminated groundwater that initiated this Superfund investigation still exists. Therefore, the no action alternative is included only as a baseline to which other alternatives may be compared.

**TABLE 3-1**
**PRELIMINARY ALTERNATIVES FOR GROUNDWATER REMEDATION**

| Groundwater Alternative | Component Technologies |
|---|---|
| 1 | No Action |
| 2 | Collection (Groundwater) and Off-Site Deep Well Injection |
| 3 | Collection (Groundwater), On-Site Carbon Adsorption and Discharge |
| 4 | Collection (Groundwater), On-Site Stripping and Discharge |
| 5 | Collection (Groundwater), On-Site Reverse Osmosis and Discharge |
| 6 | Collection (Groundwater), On-Site Chlorinolysis and Discharge |
| 7 | Collection (Groundwater), On-Site Hydrolysis and Discharge |
| 8 | Collection (Groundwater), On-Site Ozonolysis, Photolysis, and Discharge |
| 9 | Collection (Groundwater), On-Site Wet Air Oxidation and Discharge |
| 10 | Collection (Groundwater), On-Site Catalytic Dehydrochlori-nation |
| 11 | Collection (Volatile Gases) and Discharge |

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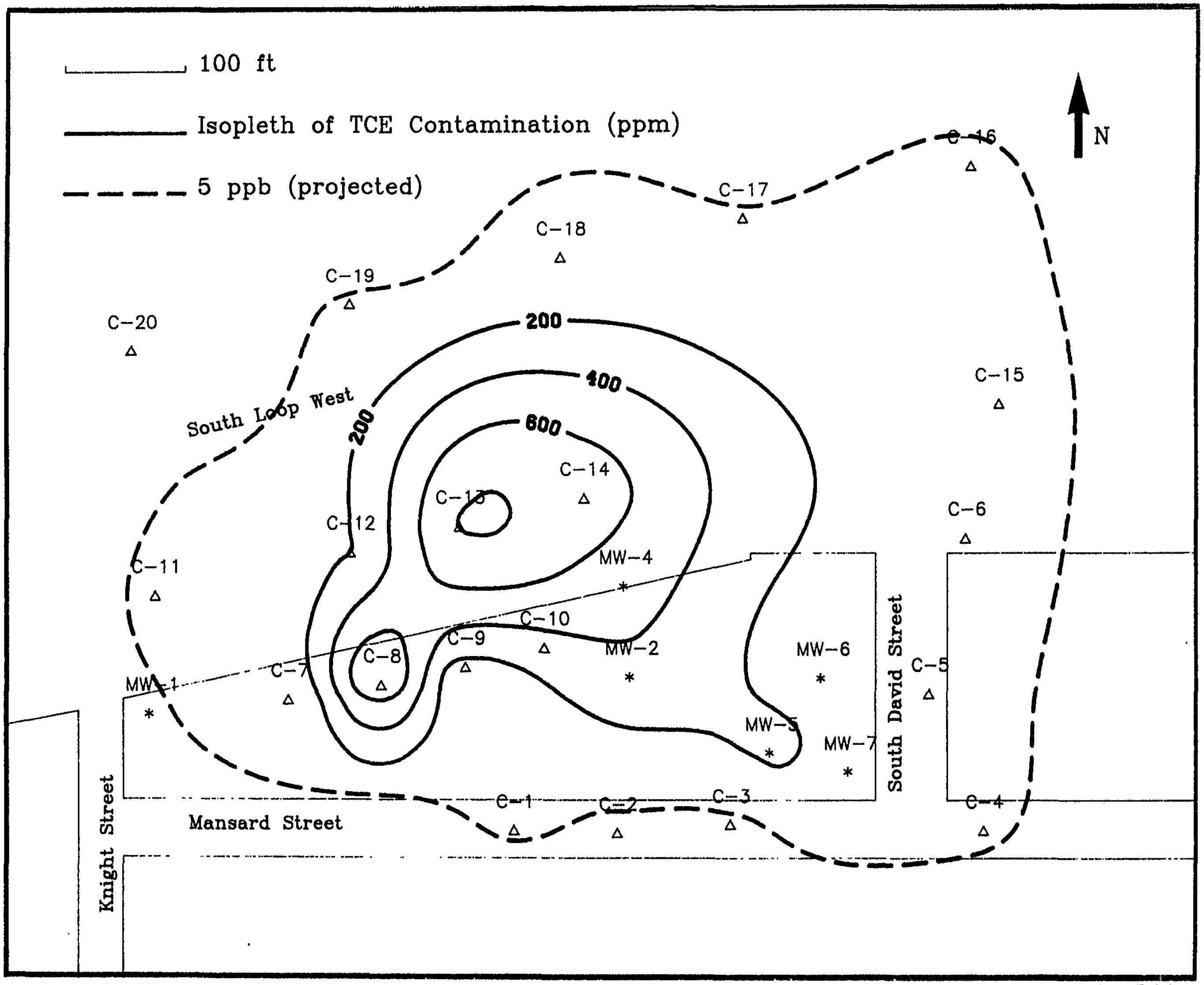


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Figure 3-1
TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit

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### 3.2.2 Groundwater Alternative 2 - Collection (Groundwater) and Off-Site Deep Well Injection

With this alternative, the groundwater will be pumped from the subsurface with recovery wells, and the water will be stored in tanks temporarily. A vacuum truck will schedule regular pick-ups of the fluids for transportation and disposal at an injection well facility off-site.

Deep well injection as a form of disposal has been used since the 1930's to isolate aqueous wastes within the natural subsurface storage vaults created by impermeable layers of clays and shales. Deep well injection does not provide treatment of the wastes but does provide for long-term containment of the wastes.

### 3.2.3 Groundwater Alternative 3 - Collection (Groundwater), On-Site Carbon Adsorption, and Discharge

Alternative 3 encompasses pumping the contaminated groundwater with recovery wells, transporting it to a temporary storage tank, passing the water through activated carbon columns stationed on-site, and to an additional storage tank prior to disposal or discharge. Once spent, the carbon will require off-site thermal regeneration or disposal at a landfill. The groundwater will be tested and discharged if it meets the appropriate discharge requirements for one of the discharge options listed in Section 3.2.12. The groundwater may require pretreatment (solids removal) to prevent clogging of the adsorption sites on the activated carbon. Carbon adsorption may occur by batch, column, or fluidized-bed operations. Typical contacting systems are fixed bed or countercurrent moving beds (Knox, et al., 1986). Both fixed and moving bed operations may use gravity or pressure flow. Because they all offer adequate treatment capabilities, the type of carbon adsorption unit chosen for use at the ITS site will be based on availability and economics.

Activated carbon works on the principle that as the water passes through the carbon, the organic contaminants are attracted to the carbon surfaces and held by chemical and/or physical forces. The activated carbon




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process, per se, does not provide destruction or even permanent immobilization of TCE. Activated carbon acts essentially as an adsorbent to remove TCE from the water and concentrate it onto the carbon. The carbon will then require additional treatment or disposal prior to discharge or reinjection.

### 3.2.4 Groundwater Alternative 4 - Collection (Groundwater), On-Site Stripping, and Discharge

Alternative 4 encompasses the following components:

- Pumping of contaminated groundwater from the subsurface with recovery wells;
- Temporary storage in an above-ground tank;
- Treatment with a stripping tower; and
- Discharge or disposal of the treated water using one of the discharge options listed in Section 3.2.12.

Air stripping does not provide for destruction or permanent immobilization of TCE. Instead, air stripping allows the transfer of the TCE and other volatiles from solution in water to a solution in gas (air) where the contaminant is greatly diluted.

Four basic configurations for air stripping processes are: packed column, diffused air basin, coke tray aerator, and cross flow tower. Knox, et al. (1986) have determined the countercurrent packed tower is most effective for treating contaminated groundwater for the following reasons:

- The packed tower configuration provides the most surface area to promote better gas transfer;
- High air-to-water ratios are possible; and
- If necessary, the packed tower may be connected to vapor recovery equipment to control volatile emissions to the atmosphere.





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After passing through the stripping tower, the water will be discharged using one of the options listed in Section 3.2.12. Sampling and laboratory analyses of the effluent will be required prior to discharge or reinjection to ensure the effluent meets discharge criteria.

3.2.5 Groundwater Alternative 5 - Collection (Groundwater), On-Site Reverse Osmosis, and Discharge

This alternative encompasses pumping the groundwater with recovery wells and then storing the water temporarily prior to treatment and discharge. Reverse osmosis (RO) treatment utilizes a semipermeable membrane under high pressure to separate dissolved contaminants and other waste materials greater than 0.001 microns in diameter from a waste stream. The high pressure in the system counteracts the osmotic pressure of the dissolved constituents and acts as the driving force to concentrate the wastes behind the membrane. Clean water is forced out through the membrane. Pretreatment of the waste stream to remove suspended solids may be required to prevent irreversible fouling of the membrane used for the osmosis.

Typically used in the water treatment industry, RO has demonstrated an ability to also treat wastewaters. Various studies have shown that RO can remove certain organic chemicals, including benzene, carbon tetrachloride, tetrachloroethylene (PCE) and TCE (Sorg and Love, 1984). Various types of membranes may be used for the separation, but a thin film composite (TFC) membrane has shown greater ability to reject volatile organic compounds. This method does not provide for destruction or permanent immobilization of TCE. RO is a concentration technology that removes the TCE from the groundwater and concentrates it into a waste stream of reject water comprising approximately 25% of the water treated (Snoeyink, et al., 1984). The reject water then requires some type of disposal or additional treatment prior to discharge with one of the options listed in Section 3.2.12.





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### 3.2.6 Groundwater Alternative 6 - Collection (Groundwater), On-Site Chlorinolysis, and Discharge

Alternative 6 consists of pumping groundwater with recovery wells, storing the water temporarily, treating the water with the chlorinolysis process, and then discharging the treated water with one of the options listed in Section 3.2.12. Chlorinolysis converts the TCE into carbon tetrachloride, which may then be resold or disposed.

Prior to implementation of the alternative, a treatability study and a determination of potential purchasers of the carbon tetrachloride are recommended. The treatability study will determine the effectiveness of the chlorinolysis process to transform the TCE and assist in determining the amount of carbon tetrachloride that will be produced. If the amount of tetrachloride is too small to economically be sold, it will be disposed under RCRA regulations.

### 3.2.7 Groundwater Alternative 7 - Collection (Groundwater), On-Site Hydrolysis, and Discharge

This alternative encompasses pumping the groundwater with recovery wells and temporarily storing the water prior to treatment with hydrolysis and subsequent discharge with one of the options listed in Section 3.2.12. Hydrolysis is a naturally occurring family of reactions in which an organic molecule reacts with water to cleave one carbon-functional group bond to form a new carbon-oxygen bond. For example, TCE may be transformed by water to an alcohol. The alcohol may then require further treatment prior to discharge.

This alternative will also require a treatability study prior to implementation.

### 3.2.8 Groundwater Alternative 8 - Collection (Groundwater), On-Site Ozonolysis, Photolysis, and Discharge

Alternative 8 consists of the following steps: pumping the groundwater with recovery wells, treating the water with ozone in a reactor in the presence of ultraviolet light to destroy the TCE, and discharging the treated water using one of the options listed in Section 3.2.12. Ozonolysis is a





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process in which ozone is used to oxidize chlorinated hydrocarbon wastes containing less than 1% oxidizable materials.

This method will require a treatability study prior to implementation to determine the effectiveness at this site, of the process, the ozone dosing rate, and the retention time. In addition, ozone levels in the air near the reactor and in the effluent will require close monitoring to prevent levels toxic to humans.



### 3.2.9 Groundwater Alternative 9 - Collection (Groundwater), On-Site Wet Air Oxidation, and Discharge

Alternative 9 includes pumping of contaminated groundwater with recovery wells, temporary storage, treatment by wet air oxidation in a specially designed reactor, and discharge using one of the options listed in Section 3.2.12. A treatability study will aid in determining the ability of the method to destroy TCE and the most effective reactor pressure, operating temperatures, retention times, and use of catalysts.

### 3.2.10 Groundwater Alternative 10 - Collection (Groundwater), On-Site Catalytic Dehydrochlorination, and Discharge

Alternative 11 encompasses the following components:

- Pumping of the contaminated groundwater with recovery wells;
- Temporary storage;
- Treatment in a reactor with alkali metal, potassium hydroxide (KOH), and tetraethylene glycol (TEG) to remove hydrogen and chlorine molecules from the TCE (forming end products of chloride salts, water and an elimination product); and
- Discharge of the treated water using one of the options listed in Section 3.2.12.

Sampling and laboratory analyses would be required to ensure that the effluent meets appropriate discharge regulations. Also required would be a treatability study to determine the effectiveness of the method at this site. A toxicity test is recommended to prove the degree of non-toxicity of the end products of the dehydrochlorination process.

An advantage of this alternative is that a dechlorination reactor has already been proposed for testing at the ITS site to remediate soils contaminated with PCBs. The same reactor could possibly be used to remediate both the soils and the groundwater, thereby cutting capital costs. In fact, the soils and groundwater could be treated together in the reactor as long as both reagents are included (Rodgers, 1988).

### 3.2.11 Groundwater Alternative 11 - Collection (Volatile Gases) and Discharge

Alternative 11 includes the ventilation of soil and shallow groundwater to volatilize the TCE so that the contaminated air may be directed to the ground surface for release. Air treatment equipment may be used to scrub the air prior to release to the atmosphere.

A treatability study is recommended prior to full-scale implementation to determine effectiveness of the treatment and design parameters such as placement of venting wells and radii of influence.

### 3.2.12 Discharge Options

These are the options which may be combined with any of the groundwater treatment alternatives for discharge of remediated groundwater.

#### 3.2.12.1 Discharge Option 1 - Reinjection

Reinjection encompasses pumping the withdrawn, treated groundwater back into the water-bearing zones. Pumps would likely be used to move the treated water from a storage tank, down a well, and into the zones from which it originated.





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3.2.12.2 Discharge Option 2 - Discharge to POTW

Discharge to a POTW is an effective method to discharge treated water if adequate treatment is accomplished. The water is discharged to a sanitary sewer for transport to the POTW. The discharger is required to obtain permission from the City of Houston Public Works Department and to pay all fees associated with this option. As discussed previously, the biological degradation of TCE and products of degradation are in question. Therefore, pretreatment of TCE is assumed to be necessary.

3.2.12.3 Discharge Option 3 - Discharge to Storm Sewer

This option is required to meet all technical requirements of an NPDES permit prior to discharging treated groundwater to one of the ditches near the site or directly to a storm sewer.

## 3.3 SCREENING OF GROUNDWATER ALTERNATIVES

In this section, the preliminary groundwater alternatives will be compared to each other based on effectiveness (ability to reduce public health and environment impacts) and implementability. The alternatives clearly not equivalent in terms of effectiveness and implementability to the others will be eliminated from consideration.

Effectiveness as used here refers to the ability of an alternative to reduce public health risk and adverse environmental impacts compared to the "No Action" and other alternatives.

The implementability of each alternative is discussed to determine the ease of installation and construction for an alternative. Implementability also concerns the time required to achieve the specified level of remediation. Table 3-2 summarizes the preliminary screening of the groundwater alternatives.

Section 3.3.12 preliminarily screens the three discharge options, one of which will be used as part of a remedial alternative. Screening criteria are also effectiveness and implementability.





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**TABLE 3-2**
**PRELIMINARY SCREENING OF ALTERNATIVES FOR GROUNDWATER REMEDIATION**

| Groundwater Alternative | Type of Remediation Offered | Warrants Further Consideration |
|---|---|---|
| 1. No Action | None | Yes |
| 2. Collection (Groundwater) and Off-Site Deep Well Injection | Isolation/Removal | Yes |
| 3. Collection (Groundwater), On-Site Carbon Adsorption, and Discharge | Removal/Concentration | Yes |
| 4. Collection (Groundwater), On-Site Stripping, and Discharge | Removal | Yes |
| 5. Collection (Groundwater), On-Site Reverse Osmosis, and Discharge | Removal/Concentration | No |
| 6. Collection (Groundwater), On-Site Chlorinolysis, and Discharge | Destruction | No |
| 7. Collection (Groundwater), On-Site Hydrolysis, and Discharge | Destruction | No |
| 8. Collection (Groundwater), On-Site Ozonolysis, Photolysis, and Discharge | Destruction | No |
| 9. Collection (Groundwater), On-Site Wet Air Oxidation, and Discharge | Destruction | No |
| 10. Collection (Groundwater), On-Site Catalytic Dehydrochlorination and Discharge | Destruction | Yes |
| 11. Collection (Volatile Gases) | Removal | No |

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### 3.3.1 Groundwater Alternative 1 - No Action

The no action alternative will not eliminate any routes of exposure. However, the existing routes are discussed here to establish a baseline by which the other alternatives can be judged.

The potential routes of exposure to TCE associated with the ITS site include:

- Ingestion of contaminated groundwater; and
- Inhalation of TCE vapors during excavation activities at the site.

The primary exposure route affecting public health is ingestion of contaminated groundwater. Data from the RI show TCE levels in the groundwater ranging from none detected to 790 ppm. Ingestion would occur by drinking water from wells screened in the water-bearing units currently contaminated with TCE or by the TCE migrating to other water-bearing units that supply drinking water.

An inventory of water wells within a one-mile radius of the site shows 24 wells. Information on total well depth, where available, shows wells to be completed at a variety of depths from 77 to 844 feet. (This information is shown in the Phase I RI.) This inventory did not determine the use of the water or the screened intervals of the wells.

While no wells appear to be screened in the uppermost water-bearing unit, all water wells are not necessarily registered with the state. The fact that the TCE appears to be migrating vertically through the aquitards puts deeper aquifers at risk, and various populations stand the risk of possible exposure to TCE via the ingestion of contaminated groundwater route. Furthermore, the State of Texas does not have the authority to implement institutional controls for groundwater usage.



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**Effectiveness** - The no action alternative does not eliminate the potential threat to drinking water supplies because the TCE will continue to migrate vertically and horizontally.

**Implementability** - The no action alternative is relatively easily implemented. Every five years a reassessment of the site would be required to determine the extent of contamination and the desirability to continue the no action alternative.

The no action alternative will be considered further as a baseline, i.e., a "worst case" scenario, to which the other alternatives may be compared.

### 3.3.2 Groundwater Alternative 2 - Collection (Groundwater) and Off-Site Deep Well Injection

**Effectiveness** - This alternative provides for isolation of the contaminated groundwater deep below the earth's surface once it is pumped from the subsurface. The effectiveness of this alternative is limited by the ability of the collection system to remove the majority of the contaminated water. In addition, as long as TCE remains adsorbed to the soils at levels greater than the cleanup criterion, the possibility of further groundwater contamination exists. This is true of all of the groundwater collection alternatives.

Removal efficiency for a solute such as TCE is related directly to Kow, the octanol-water partition coefficient, and inversely to water solubility. Kow for TCE equals $1x10^{2.29}$, and the water solubility of TCE is 1100 ppm at $20^{o}C$. The Kow for TCE is rather low, indicating a low removal efficiency for TCE.

**Implementability** - The well installation portion of this alternative will be rather easily implementable, depending on the final locations of withdrawal wells. For example, locating wells on the northern side of Loop 610



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would require maneuvering between the highway and feeder road and result in transporting that water across the highway for on-site storage. In addition, access might be a problem north of the site.

Transport by tank truck of the large volume of water involved is implementable, but may be a traffic hazard.

Even so, this alternative will be considered further.

### 3.3.3 Groundwater Alternative 3 - Collection (Groundwater), On-Site Carbon Adsorption, and Discharge

Effectiveness - Carbon adsorption is a proven, effective method of removing TCE from contaminated groundwater. Potentially less effective are the methods for treating the spent carbon. While thermal regeneration results in destruction of organics, landfilling immobilizes the contaminants only for as long as the liner remains intact. Thermal regeneration off-site will be assumed for this alternative. The effectiveness of this alternative is limited by the ability of the withdrawal system to collect the contaminated groundwater.

Implementability - The components to this alternative are easily obtained and installed on-site. Activated carbon is widely used and supplied by several vendors. While no specific tests were performed to determine suspended solids content of groundwater from either aquifer, examinations of bailed formation waters that had been allowed to sit undisturbed for several days showed a significant solids concentration. Thus, pretreatment such as solids removal may be required prior to carbon adsorption because the solids tend to clog adsorption sites on the carbon, inhibiting organics adsorption. In addition, implementability may be limited by lack of access for installing recovery wells north of the site.

This alternative will be considered further.





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### 3.3.4 Groundwater Alternative 4 - Collection (Groundwater), On-Site Stripping, and Discharge

Effectiveness - Air stripping, mostly applicable to aqueous streams containing less than 1% volatiles, has been successfully used for removing volatile organics from groundwater in the past. Removal efficiencies range from 10% to greater than 90% (Guswa, et al., 1984). Temperature has a great effect on removal efficiency, especially for soluble compounds (Knox, et al., 1986), ie. a higher temperature will cause the TCE to volatilize more readily

Implementability - Air stripping is easily implementable, and numerous vendors supply stripping equipment. Implementation time will be governed by the hydraulics of the groundwater recovery system.

This alternative will be considered in more detail.

### 3.3.5 Groundwater Alternative 5 - Collection (Groundwater), On-Site Reverse Osmosis, and Discharge

Effectiveness - The effectiveness of reverse osmosis varies depending on factors such as leachate variability, growth of organisms on the filtering membranes, and total suspended solids content of groundwater. Pretreatment may be required to control these factors. Effectiveness also varies for membrane type and retention time. Sorg and Love (1984) cite TCE removal efficiencies of 78 to 99% and 30 to 89%.

As with the other alternatives, effectiveness of this alternative will be limited by the ability of the recovery system to withdraw the contaminated water.

Implementability - While the equipment for reverse osmosis can be readily obtained, the filtering membrane fouls quickly, allowing contaminants to pass through, and has not been shown to return to the same removal efficiency after cleaning. In addition, the quantity of water rejected by the membrane is high 25 to 33% (Sorg and Love, 1984), and will require additional treatment. For these reasons this alternative is screened from further consideration.

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### 3.3.6 Groundwater Alternative 6 - Collection (Groundwater), On-Site Chlorinolysis, and Discharge

Effectiveness - Chlorinolysis is a manufacturing process capable of converting the TCE in contaminated groundwater to carbon tetrachloride. The groundwater to be treated must be free of solids and contain fewer than 25 ppm sulfur, less than 5% non-chlorinated aromatic hydrocarbons, and almost no oxygen containing organics. Because this process was developed as a production process, no information is presented in the literature on the percentage conversion of a typical influent waste mixture such as contaminated groundwater to carbon tetrachloride (Berkowitz, 1978).

Implementability - Implementation of this alternative will be difficult. The necessary equipment is not readily available and, if it could be obtained, start-up problems would be likely. In addition, once the carbon tetrachloride is produced, it must be disposed or sold. Because the amount of carbon tetrachloride that will be produced is anticipated to be relatively small, the recovered resource cannot be economically marketed and will require further disposal or treatment.

This alternative is screened from further consideration because chlorinolysis has not been proven effective for treatment of TCE contaminated groundwater, and the alternative will encounter difficulties in implementation.

### 3.3.7 Groundwater Alternative 7 - Collection (Groundwater), On-Site Hydrolysis, and Discharge

Effectiveness - Hydrolysis is a reaction in which chlorinated hydrocarbons react with water, cleaving one carbon-chloride bond to form an alcohol. Hydrolysis involves a family of chemical reactions whose rates are governed by temperature, pH, and the presence of catalysts. Various pesticide plants utilize hydrolysis to treat their waste streams with removal rates ranging from 87.4% to greater than 99.9% for all constituents (Jett, 1982). Elevated temperatures and/or elevated pH were typically the driving forces behind the hydrolysis process; however, the reactors were typically open to the atmosphere, and volatilization may also have been occurring. While hydrolysis appears effective, this method has not been proven effective for remediating TCE contaminated groundwater. Furthermore, the cost-effectiveness will be governed by the ability of the well system to recover the TCE.

Implementability - Treatment in a hydrolysis reactor, which may be readily obtained, would be relatively easy. Using two flow-through basins with dimensions of 100 ft. x 5 ft. x 3 ft. and an average retention time of 7 days results in a system throughput of 3200 gallons per day (GPD). However, this area requirement is prohibitive at the ITS site. The available land area may limit the groundwater withdrawal rate. 001322

Therefore, Groundwater Alternative 7 will not be considered further because it has not been proven effective for TCE destruction in groundwater.

### 3.3.8 Groundwater Alternative 8 - Collection (Groundwater), On-Site Ozonolysis, Photolysis, and Discharge

Effectiveness - Ozonolysis is a chemical oxidation method utilizing ozone to destroy organics. Ozone in particular has a higher oxidation potential than hydrogen peroxide, potassium permanganate, chlorine, hypochlorites, or chlorine oxide. The oxidation process must be completed to ensure total oxidation because intermediate products may be more toxic than the starting compounds (Paulson, 1977). Ultraviolet light tends to increase the rate of destruction. This method is innovative in the treatment of hazardous wastes and a literature search did not yield information on the effectiveness of treating chlorinated hydrocarbon wastes including TCE-contaminated groundwater with this method.

Implementability - Implementability of this alternative is similar to that of other "pump and treat" remediations, e.g. the reactor and ozone are readily available, and the treatment will be limited by the ability of the withdrawal system to remove the contaminated groundwater. In addition, a treatability study is recommended prior to a full-scale implementation.

The use of ozonolysis and photolysis, or photoozonolysis, to treat chlorinated hydrocarbons to the required remediated level has not been proven effective and will, therefore, be screened from further consideration.

3.3.9 Groundwater Alternative 9 - Collection (Groundwater), On-Site Wet Air Oxidation, and Discharge

Effectiveness - Wet air oxidation (WAO) is a thermal oxidation process that occurs at elevated pressures and effectively treats hazardous organic waste streams that are too dilute to incinerate and too toxic to biologically treat. The primary products of WAO include $CO_2$ and $H_2O$ while the halogens remain in the aqueous phase. A series of priority pollutants have been tested in a bench scale WAO reactor, and in most cases, greater than 99% destruction was observed (Dietrich, et al., 1985). An additional bench scale test was reported by Dietrich, et al. (1985) in which at 320°C TCE was oxidized from 500 ppm to 1.7 ppm for a 99.7% removal within 60 minutes. Laboratory studies reported by the same researchers show a reduction of 99.3% for TCE. Again, the effectiveness of this alternative will be limited by the ability of the recovery system to withdraw the contaminated water.

Implementability - While the WAO process is optimal for treating liquid wastes with low heat value, process conditions typically require a waste containing 5 to 15% oxidizable organics (Ehrhenfeld and Bass, 1983). Because the contaminated groundwater at ITS does not meet this consideration, WAO is screened from further consideration.

3.3.10 Groundwater Alternative 10 - Collection (Groundwater), On-Site Catalytic Dehydrochlorination, and Discharge

Effectiveness - Dehydrochlorination utilizes a reagent mixture of potassium hydroxide (KOH) and tetraethylene glycol (TEG). The method effectively dehydrohalogenates a variety of compounds, with the rate depending on the



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particular compound and the temperature. The effectiveness of this alternative will be governed by the ability of the recovery system to remove the contaminated groundwater from the subsurface.

**Implementability** - Because a similar process is planned for the treatment of PCB contaminated soils at the site, implementation of this process, especially obtaining the capital expenditure items, will be rather easy. However, a treatability study is necessary prior to full-scale implementation. In addition, the results of the treatability study should be used to determine if any special treatment of the process residual gases, organics, or wastewater will be required. This alternative will be considered further.

### 3.3.11 Groundwater Alternative 11 - Collection of Volatile Gases

**Effectiveness** - The success of using venting to remove methane vapors from landfills and noxious fumes from buildings has led to the use of this method for remediating contaminated soils and groundwater in situ. While this method shows promise and has been effectively used to control subsurface contamination in soils with a relatively high porosity, the method has not been proven effective for remediating contaminated groundwater.

**Implementability** - Because of the fine-grained nature of the sediments at the ITS site, the radius of influence of the venting wells would be severely limited, requiring the installation of a greater number of wells. This greatly increases the difficulty of installation and decreases the effectiveness of the cleanup. Therefore, this alternative is screened from further consideration.

### 3.3.12 Discharge Options

#### 3.3.12.1 Discharge Option 1 - Reinjection

**Effectiveness** - Reinjection is an effective method of discharging treated water. In addition, reinjection may be used to cleanup a plume more quickly by locally increasing the hydraulic gradient.

Implementability - The implementability of this alternative is limited by the cleanup criterion of 5 ppb. This criterion should be attained by the treatment system.

Therefore, this option will be considered in more detail.

3.3.12.2 Discharge Option 2 - Discharge to POTW

Effectiveness - Discharge of treated water to a POTW is an effective method to discharge treated water. In fact, the additional treatment at the POTW is not required.

Implementability - This option is readily implemented by constructing a sewage outfall on-site into the sanitary sewers running along the south side of the south feeder road to I-610. However, permission of the City of Houston Public Works Department is required and is decided on a case-by-case basis.

Thus, this option will be considered in more detail.

3.3.12.3 Discharge Option 3 - Discharge to Storm Sewer

Effectiveness - Discharge to a storm sewer is also an effective method of discharging treated groundwater.

Implementability - This option is also readily implemented; however, Chapter 19 of the City of Houston Building Code specifies that water discharged to the storm sewer may consist only of rainfall run-off. Other water sources may be not be discharged to the storm sewer system (Gallagher, 1988).

Thus, this option will not be further considered.

## 3.4 DESCRIPTION OF PRELIMINARY SUBSURFACE SOIL ALTERNATIVES

The following alternatives pertain to remediation of the subsurface soils contaminated with TCE. These alternatives are discussed in more detail below. Table 3-3 summarizes the component technologies of the subsurface soil remedial alternatives.

### 3.4.1 Subsurface Soil Alternative 1 - No Action

For this alternative, no new or additional remedial activities will be conducted at the site. However, long term soil sampling and monitoring will occur to monitor the contamination.

The no action alternative does not address potential threats to public health or the environment. However, if groundwater remediation is conducted, the soil contamination will eventually be remediated via TCE leaching into the groundwater and subsequently being removed during groundwater remediation.

### 3.4.2 Subsurface Soil Alternative 2 - Collection (Volatile Gases)

The collection of volatile gases involves the digging of trenches or wells and applying a vacuum to force air to move through the soils to increase the volatilization of the TCE. A vacuum placed on the wells or trenches creates a pressure differential so that air flows from the high pressure in the soils to the low pressure in the wells. The TCE is carried out with the air and may then be vented to the atmosphere or treated.

This alternative does not destroy the TCE, but results in the removal of TCE from one medium (water) to another (ambient air, activated carbon).

**TABLE 3-3**
**PRELIMINARY ALTERNATIVES FOR SUBSURFACE SOIL REMEDIATION**

| Subsurface Soil Alternative | Component Technologies |
|---|---|
| 1 | No Action |
| 2 | Collection (Volatile Gases) |
| 3 | Containment, Soil Washing, Collection (Water), Treatment |

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### 3.4.3 Subsurface Soil Alternative 3 - Containment, Soil Washing, Collection (Water), and Treatment or Disposal

Alternative 3 includes the following steps:

- Containment of the plumes with slurry walls;
- Flushing the contaminated soils within the contained area with water;
- Collection of the flush water within the slurry walls; and
- Treatment of the flush water with the treatment method chosen to remediate the groundwater.

## 3.5 SCREENING OF SUBSURFACE SOIL ALTERNATIVES

In this section, the preliminary subsurface soil alternatives are compared to each other based on effectiveness and implementability. Those alternatives clearly not equivalent in terms of the two preliminary screening criteria (effectiveness and implementability) to other alternatives are eliminated from further consideration.

Table 3-4 summarizes the preliminary screening of the subsurface soil alternatives.

### 3.5.1 Subsurface Soil Alternative 1 - No Action

Soil contamination at the site acts as a continuing source of groundwater contamination which may eventually be remediated by groundwater cleanup methods.

Effectiveness - The no action alternative does not eliminate the potential threat to drinking water supplies caused by continued leaching of TCE from the soil.

Implementability - The no action alternative is readily implemented. Additional monitoring is recommended approximately every five years to determine the extent of contamination and the desirability of continuing this alternative.

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**TABLE 3-4**
**PRELIMINARY SCREENING OF ALTERNATIVES FOR SUBSURFACE SOILS REMEDIATION**

| Subsurface Soil Alternative | Type of Remediation Offered | Warrants Further Consideration |
|---|---|---|
| 1. No Action | None | Yes |
| 2. Collection (Volatile Gases) | Removal | No |
| 3. Containment, Soil Washing, Collection (Water), Treatment | Removal | No |

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### 3.5.2 Subsurface Soil Alternative 2 - Collection (Volatile Gases)

**Effectiveness** - The collection of subsurface volatile gases, or soil venting, is used by various vendors to remove volatile components from contaminated soils. However, the method has only been proven for high porosity, sandy soils. This would not be effective in the clays at this site.

**Implementability** - While the equipment to implement this alternative is readily obtained and installed, soil venting has not been proven for remediation of clay soils. Therefore, this alternative will not be considered further.

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### 3.5.3 Subsurface Soil Alternative 3 - Containment, Soil Washing, Collection (Water), and Treatment

This alternative is differentiated from the no action soil cleanup alternative combined with groundwater remediation by the intent of this alternative to actively flush the contaminated clay. No action soil cleanup with groundwater remediation will accomplishing some soil washing as part of groundwater remediation. The effectiveness and time required for this alternative have not been determined.

**Effectiveness** - While the soil washing method has been proven effective for sandy soils, this alternative has not been shown to be effective on clayey soils.

**Implementability** - The components required to implement this alternative are readily obtained and installed. Even so, implementation may require years to attempt to flush all of the soils with concentrations greater than the cleanup criterion.

Because this method is ineffective in clay soils, Alternative 3 is screened from further consideration.

## 3.6 Summary of Alternatives Screening

Table 3-5 summarizes screening of the remedial alternatives.

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TABLE 3-5
SUMMARY
SCREENING OF ALTERNATIVES

| Alternative | Screening Criteria Effectiveness | Implementable | Warrants Further Consideration | Comments |
|---|---|---|---|---|
| **Groundwater** | | | | |
| 1. No Action | No | Yes | Yes | Baseline to which other alternatives may be compared. |
| 2. Collection (Groundwater) and Off-Site Deep Well Injection | Yes | Yes | Yes | Limited by effectiveness of recovery system. |
| 3. Collection (Groundwater), On-Site Carbon Adsorption, and Discharge | Yes | Yes | Yes | " |
| 4. Collection (Groundwater), On-Site Stripping, and Discharge | Yes | Yes | Yes | " |
| 5. Collection (Groundwater), On-Site Reverse Osmosis, and Discharge | Variable | ? | No | " ; membrane fouls readily. |
| 6. Collection (Groundwater), On-Site Chlorinolysis, and Discharge | No | No | No | Carbon tetrachloride may require disposal. |
| 7. Collection (Groundwater), On-Site Hydrolysis, and Discharge | No | Yes | No | Not proven effective for TCE. |
| 8. Collection (Groundwater), On-Site Ozonolysis, Photolysis, and Discharge | No | Yes | No | Not proven effective for TCE. |
| 9. Collection (Groundwater), On-Site Wet Air Oxidation, and Discharge | Yes | No | No | Groundwater doesn't contain adequate oxidizable organics. |
| 10. Collection (Groundwater), On-Site Catalytic Dehydrochlorination, and Discharge | Yes | Yes | Yes | Limited by effectiveness of recovery system. |
| 11. Collection of Volatile Gasses | No | No | No | Not effective in fine-grained soils. |

TABLE 3-5
SUMMARY
SCREENING OF ALTERNATIVES
(continued)

| Alternative | Screening Criteria Effectiveness | Implementable | Warrants Further Consideration | Comments |
|---|---|---|---|---|
| **Discharge Options** | | | | |
| 1. Reinjection | Yes | Yes | Yes | May increase plume recovery rate. |
| 2. Discharge to POTW | Yes | Yes | Yes | Receives additional treatment at POTW. |
| 3. Discharge To Storm Sewer | Yes | No | No | Only rainfall run-off may be discharged to storm system. |
| **Subsurface Soil** | | | | |
| 1. No Action | No | Yes | Yes | Combined with Groundwater No Action alternative. |
| 2. Collection (Volatile Gases) | No | Yes | No | Not effective in fine-grained soils. |
| 3. Containment, Soil Washing, Collection (Water), and Treatment | No | Yes | No | " |





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# SECTION 4
# DESCRIPTION OF ALTERNATIVES

This section presents a detailed description and conceptual design for each alternative (both groundwater and subsurface soil) selected in the previous section. The remaining discharge options are also described. Each description will address the following points:

- The purpose of the remedial alternative;
- Description of the component technologies comprising the alternative;
- Preliminary conceptual designs;
- Long and short term operation, maintenance, and monitoring requirements for each alternative; and
- Aspects of contamination at the ITS site that the alternative does not address.

The descriptions and preliminary conceptual designs were formulated so that cost estimates could be determined. Cost estimates are detailed in Appendix C. The enclosed descriptions are conceptual only, and the final designs will be refined during design of the selected alternative based on regulatory agency policies and additional knowledge derived from further research at the site or concerning a particular remedial technology.

## 4.1 GROUNDWATER ALTERNATIVE 1 - NO ACTION

The no action alternative will consist of no treatment of the contaminated groundwater and no operation or maintenance of any type at the facility. However, annual environmental monitoring will be required to assess the horizontal and vertical migration of the TCE. Groundwater and soil samples will be collected. In addition, a review to occur every five years is budgeted into the total costs.

The no action alternative contributes to the migration of contaminants at the ITS site and may cause the adjacent populations to be exposed to

TCE. However, as suggested in the EPA guidance document, this alternative is addressed as a baseline to which all the other alternatives may be compared.

The current plume in the uppermost water-bearing unit at the site under no action is shown in Figure 4-1. Figure 4-2 shows the approximate modeled extent of the plume (the 5 ppb TCE isopleth) in that aquifer with time under no action and ideal conditions with a longitudinal dispersivity of 200 feet. Note that only the x-direction extent has been calculated, and thus, the width of the plume has been assumed. Simplifying assumptions used to predict the extent of the plume, listed in Appendix A, include the aquifer is homogeneous, isotropic, and infinite in areal extent. The longitudinal dispersivity of 200 feet was chosen because it most closely matches the observed plume for the dispersivities studied. An exact match to the observed data is not possible for the following reasons:

- the aquifer does not exactly meet the ideal conditions specified by the model;
- the time between the spill of TCE and the present can only be approximated; and
- an average longitudinal dispervisity and groundwater velocity have been assumed for the aquifer to apply the model.

The volume of groundwater contaminated with TCE at 5 ppb or greater in the upper water-bearing zone has been estimated to be 3.2 million gallons. This estimate is based on a literature-reported value of 0.30 for the porosity.

The volume of groundwater contaminated with TCE from the intermediate water-bearing zone is unknown. However, the RI did show water containing levels of TCE above the action level in that unit.

## 4.2 RECOVERY SYSTEM

The following recovery system is based on a conceptual design and will be included as the pump portion of any "pump and treat" alternative. This





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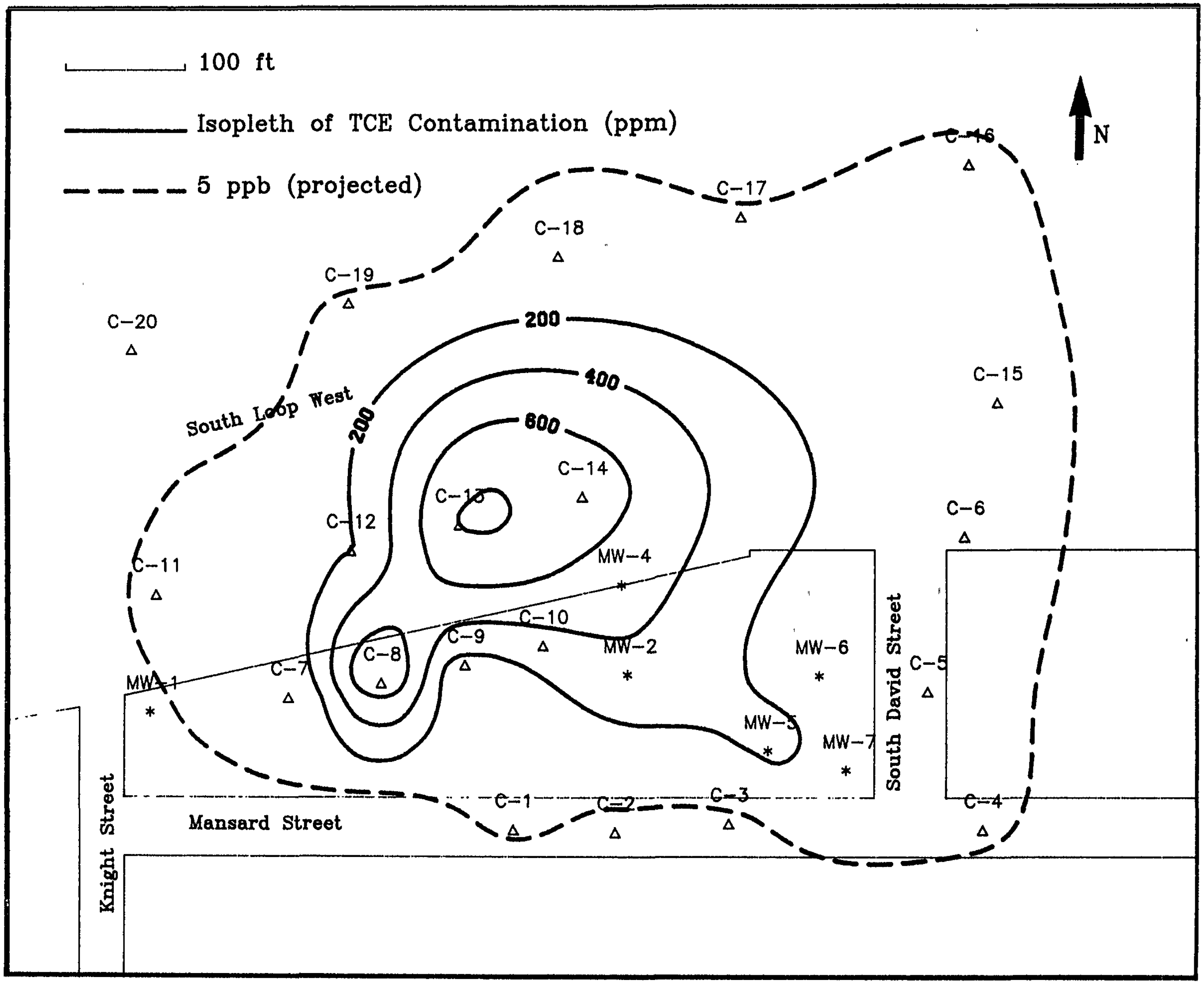


Figure 4-1
TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit

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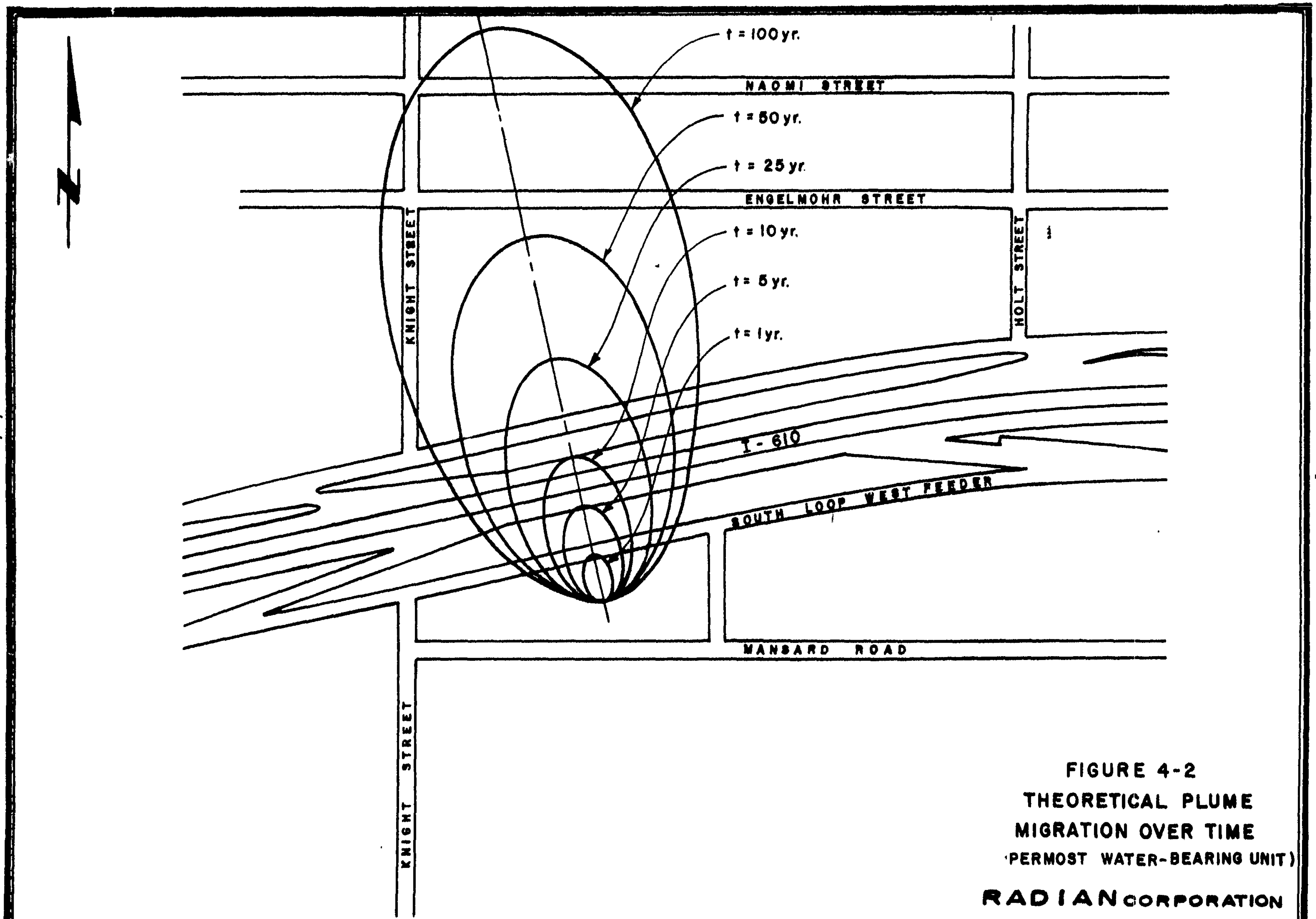


FIGURE 4-2
THEORETICAL PLUME
MIGRATION OVER TIME
(PERMOST WATER-BEARING UNIT)

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particular recovery system was chosen so that a cost estimate could be formulated for each alternative. Additional geologic, hydrologic, and geotechnical investigations are recommended prior to implementation of any recovery system. This recovery system was designed for the uppermost water-bearing unit where adequate information exists to do a conceptual design. The intermediate water-bearing unit will also require a recovery system.

The conceptual recovery system consists of ten wells on a 50-foot well spacing. The wells will be 30 feet deep and will be screened over a 10 foot interval. Figure 4-3 shows the conceptual placement of the wells. Each well will be equipped with a pump. Evidence from well bailing activities indicates a maximum pump rate of 350 gallons/day/well may possibly be sustained. The drawdown in one well pumping at that rate is shown in Figure 4-4. Cumulative drawdown for all 10 wells is shown in Figure 4-5. These calculations are shown in Appendix B. Pumping at 3500 gallons/day with the recovery system will require approximately 3 years to remove one pore volume from the uppermost aquifer with this recovery rate. Water will also be pumped from the intermediate water-bearing unit. Because residual TCE remains adsorbed to the soils and may contribute to future groundwater contamination, the removal of multiple pore volumes of contaminated groundwater is recommended in order to formulate a more accurate cost estimate. Keeping this in mind, the costs were formulated on a yearly basis. Even so, the total pumping period is assumed to be 10 years for a total volume of 12,775,000 gallons, or approximately four pore volumes from the uppermost aquifer. An additional amount of water would be pumped from the intermediate aquifer.

Potential problems that require additional investigation prior to design and installation of the final recovery system may include:

- Geotechnical investigations to determine the effects of large drawdowns on the structural stability of I-610;
- The ability of wells on the south side of I-610 to pull back contamination from the north side of the freeway;
- The extent of the plume in the uppermost aquifer to the north of the freeway and to the south and east of the site;





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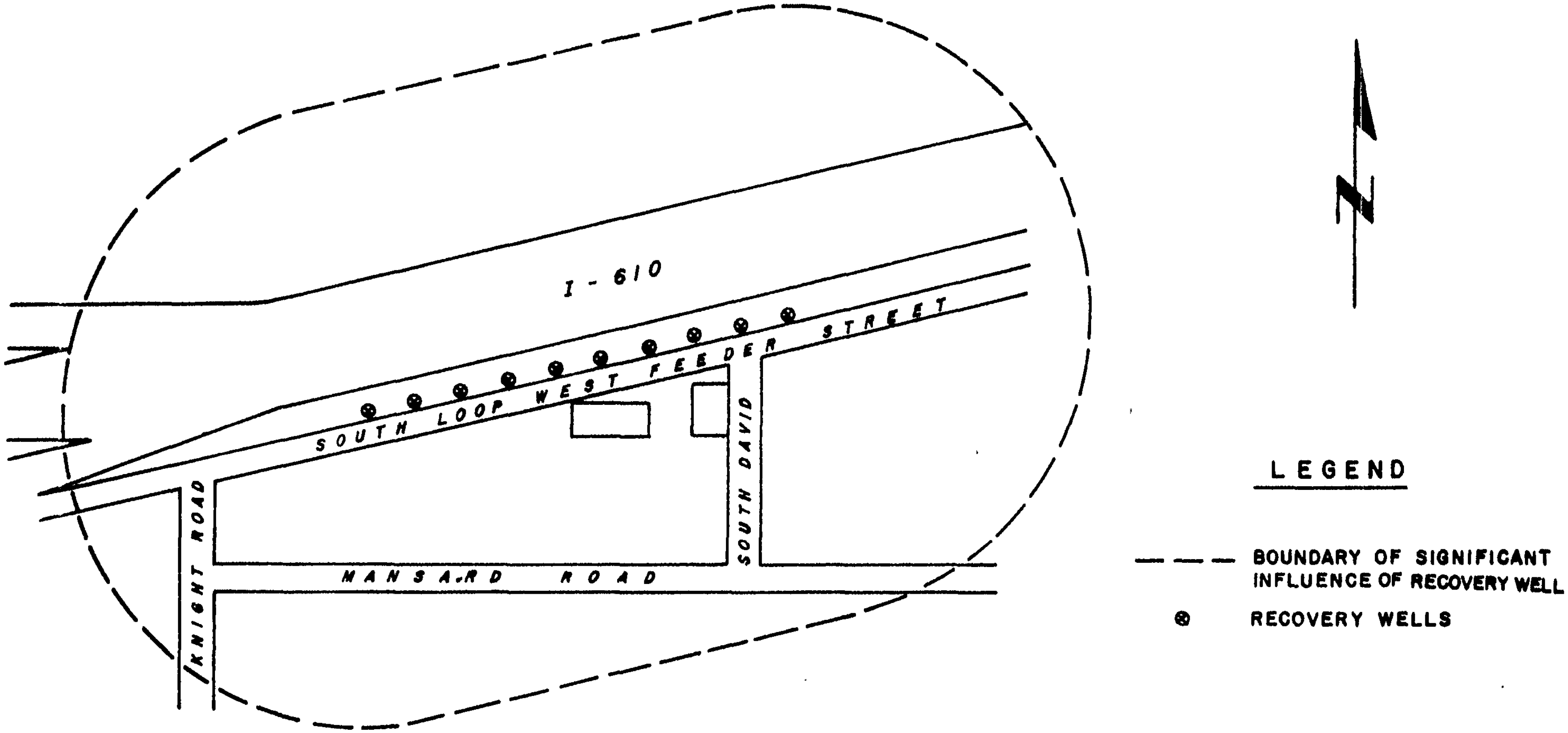


FIGURE 4-3

LOCATION OF RECOVERY WELLS
(UPPERMOST WATER-BEARING UNIT)

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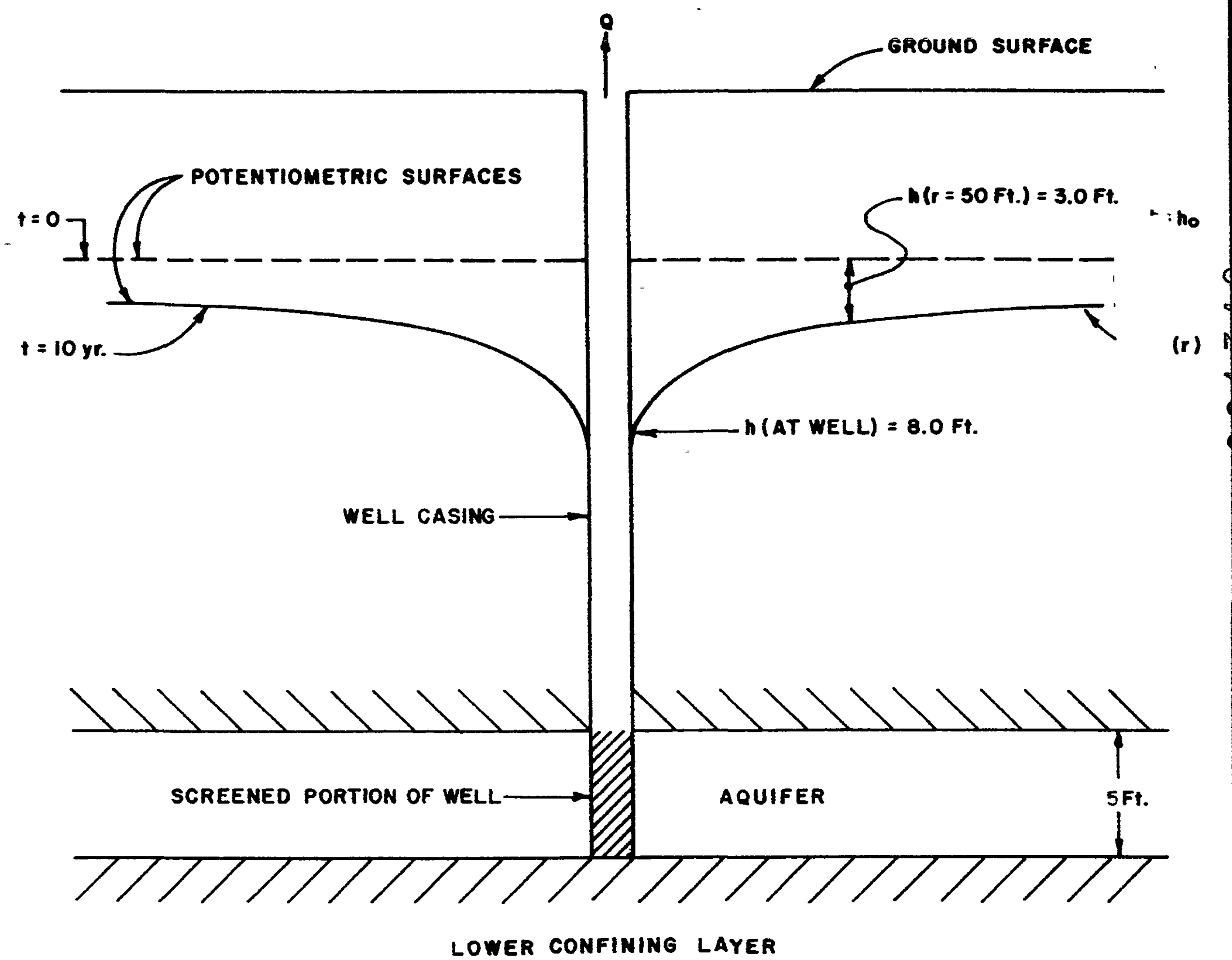


FIGURE 4-4
TYPICAL DRAWDOWN FOR ONE RECOVERY WELL
(UPPERMOST WATER-BEARING UNIT)

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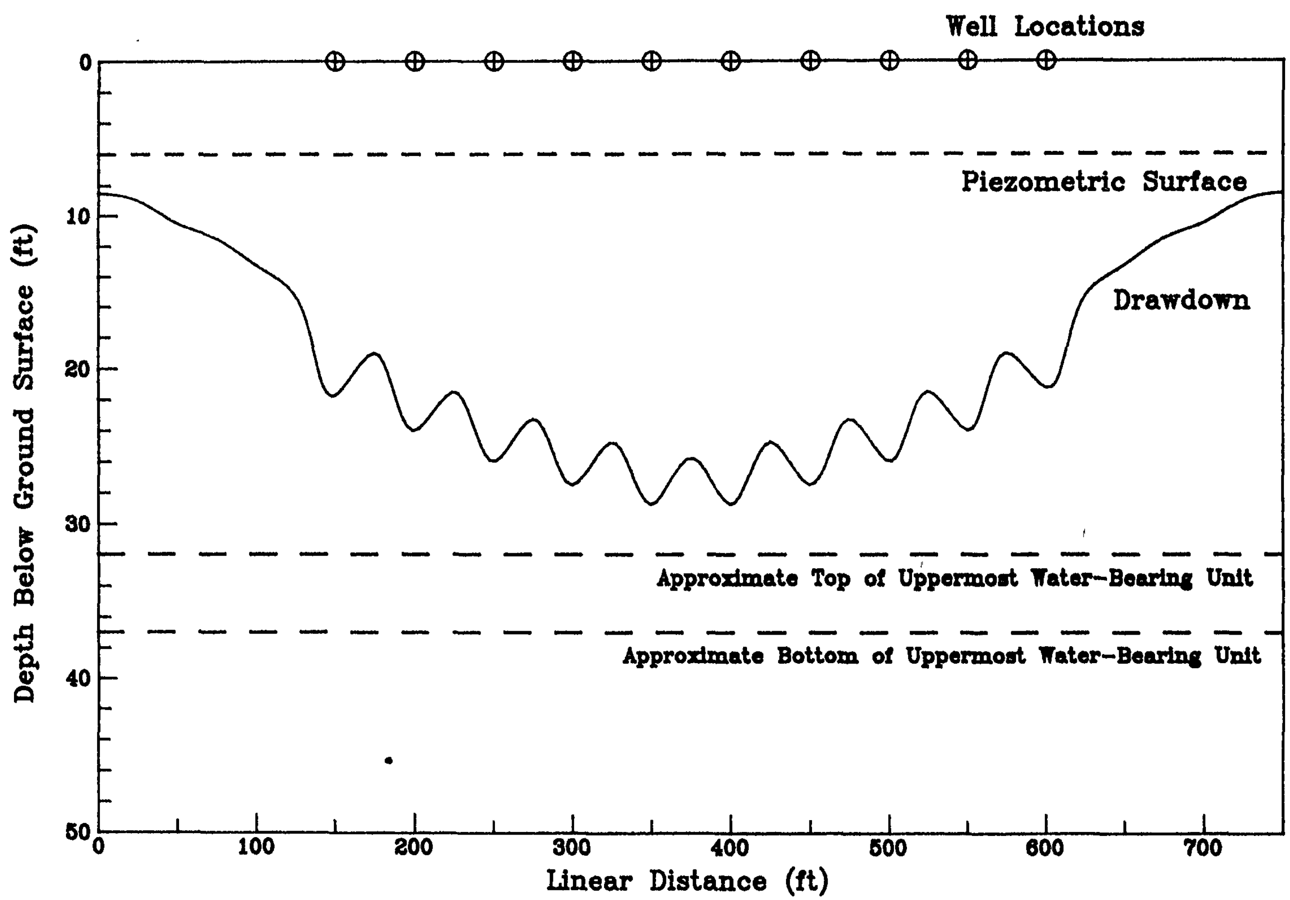


Figure 4-5 Theoretical Drawdown for 10 Wells in Recovery System – Uppermost Water-Bearing Unit

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- Investigate the "pinching out" of the water-bearing sands to the northwest and southwest of the site and investigate where the water goes if the sands do pinch out;
- Positive identification of hydraulically interconnected water-bearing units north of the site;
- Downward (vertical) rate of movement of TCE;
- The extent of contamination in the intermediate water-bearing unit;
- Additional investigation of the intermediate aquifer and under-lying clays;
- Investigation of the regional hydraulic gradient to determine if the gradient at the site changes with time or is influenced by a dewatering system or the like;
- Additional investigations and possibly laboratory studies to better determine the number of pore volumes that will require flushing;
- Collection of the additional data to use a numerical transport model to design a more effective recovery well system and a more precise cleanup time; and
- A pump test to determine hydraulics of both aquifers.

Assumptions used to design the conceptual recovery system include:

- Use of an average gradient from on-site while the wells are all placed off-site;
- Extrapolation of aquifer parameters including velocity, gradient, and direction of flow to the off-site location of the recovery system;
- Assuming that the uppermost aquifer is homogeneous, isotropic, and infinite in areal extent; and
- Assuming an additional but unknown amount of groundwater from the intermediate water-bearing unit will require remediation.

## 4.3 GROUNDWATER ALTERNATIVE 2 - COLLECTION AND OFF-SITE DEEP WELL INJECTION

The off-site deep well injection alternative will not provide treatment of the contaminated groundwater. The contaminated groundwater would be



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piped from the recovery system (described in the previous section) to a storage tank at the site. Figure 4-6 shows a diagram of the typical storage tank, and Figure 4-7 shows the proposed location of the tank on-site. The water would then be removed from the tank periodically for disposal off-site. The water would be shipped via vacuum tank truck to a deep well injection facility in compliance with EPA regulations.

The deep well facility would provide injection, isolation and monitoring of the contaminated water. Generally, these facilities will use deep clay and shale formations for confinement of the wastes. In the Gulf Coast region, the injection depths for these wells typically range from 7000 to 8000 ft. Figure 4-8 shows a cross-section of a typical off-site well used for deep well injection.

The storage tank would be located in close proximity to the South Loop West Feeder Street to facilitate vacuum tank truck loading. This location would avoid the need to decontaminate the truck at the site and would decrease the time necessary for emptying the storage tank.

The site would have to be monitored during and after remediation for evaluation of the effectiveness of the alternative. These monitoring wells would be used to determine if remediation was occurring as planned.

Upon completion of the treatment, the equipment used for remediation at the site would be decontaminated in accordance with EPA regulations. This includes: the storage tank, the well casings, and the piping from the wells to the tank.

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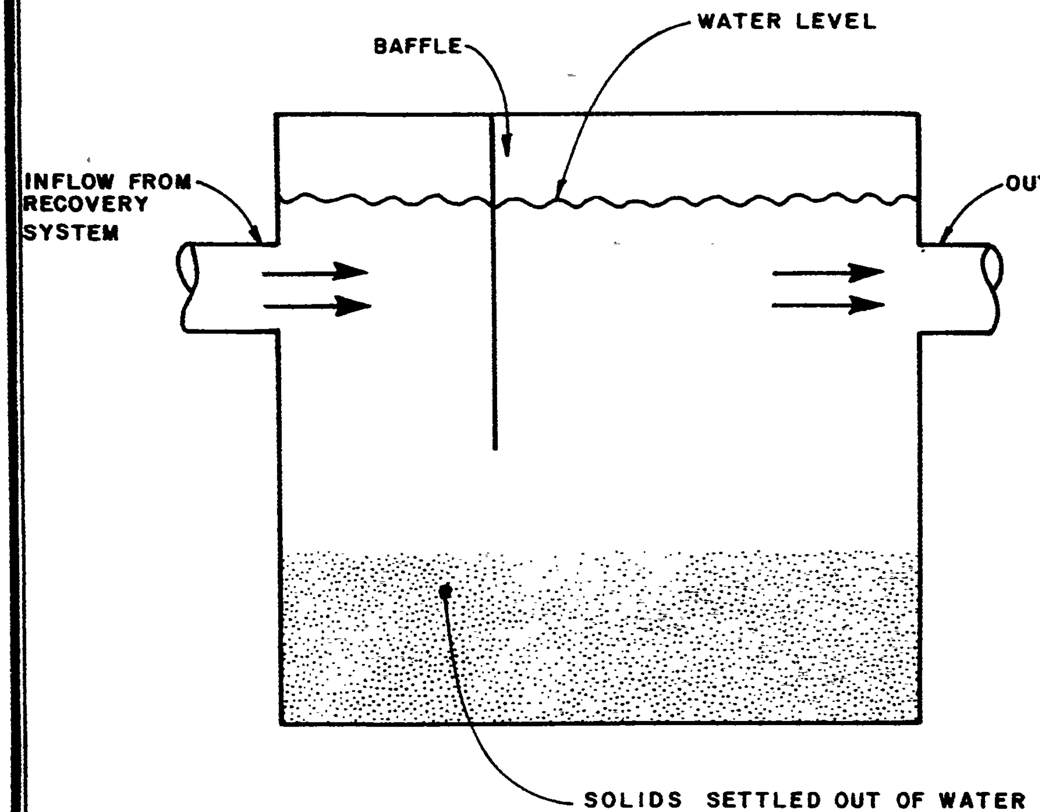


FIGURE 4-6

TYPICAL PRIMARY STORAGE TANK

NOT TO SCALE

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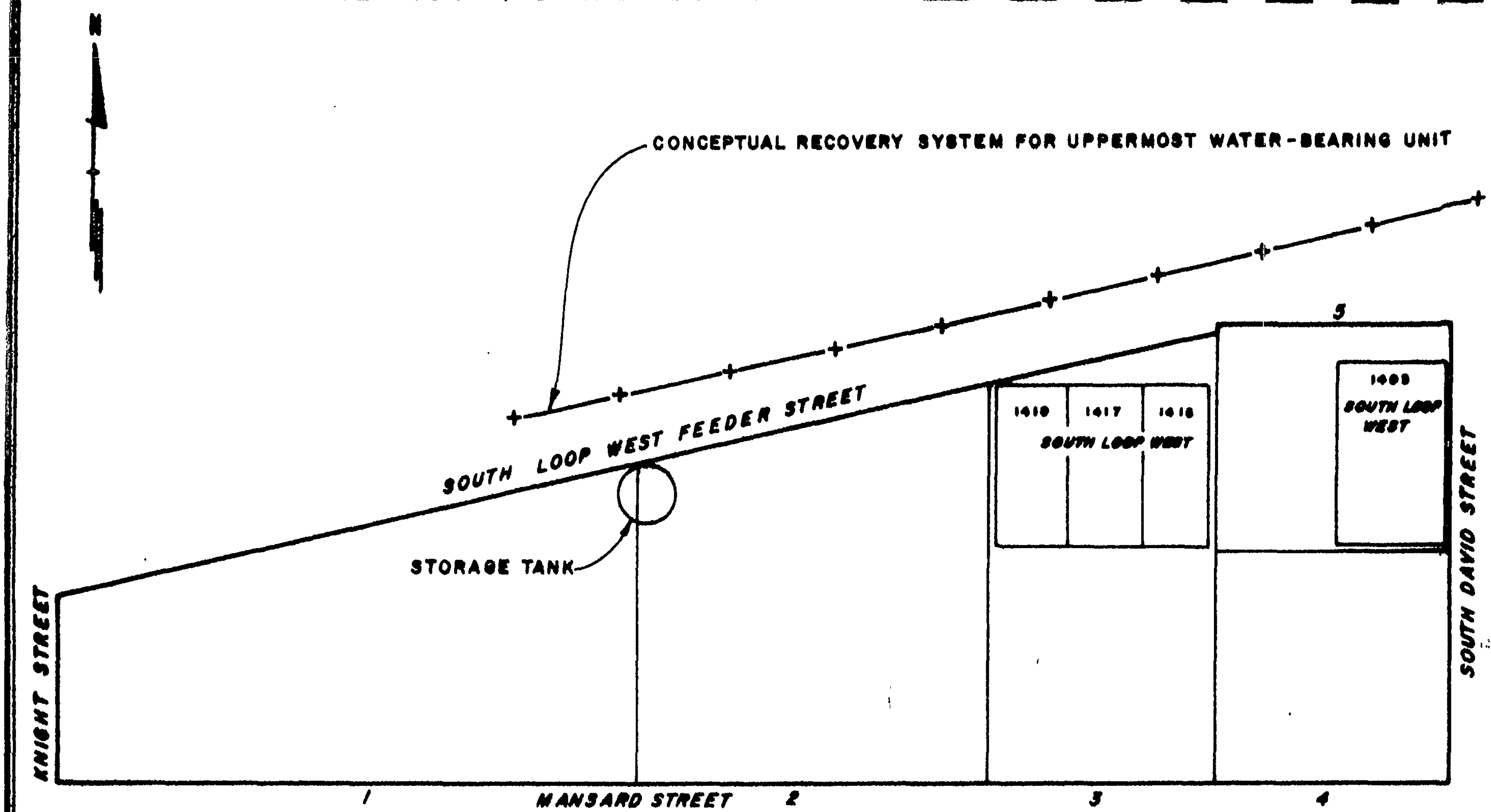


FIGURE 4-7

PROPOSED STAGING AREA FOR ALTERNATIVE 2

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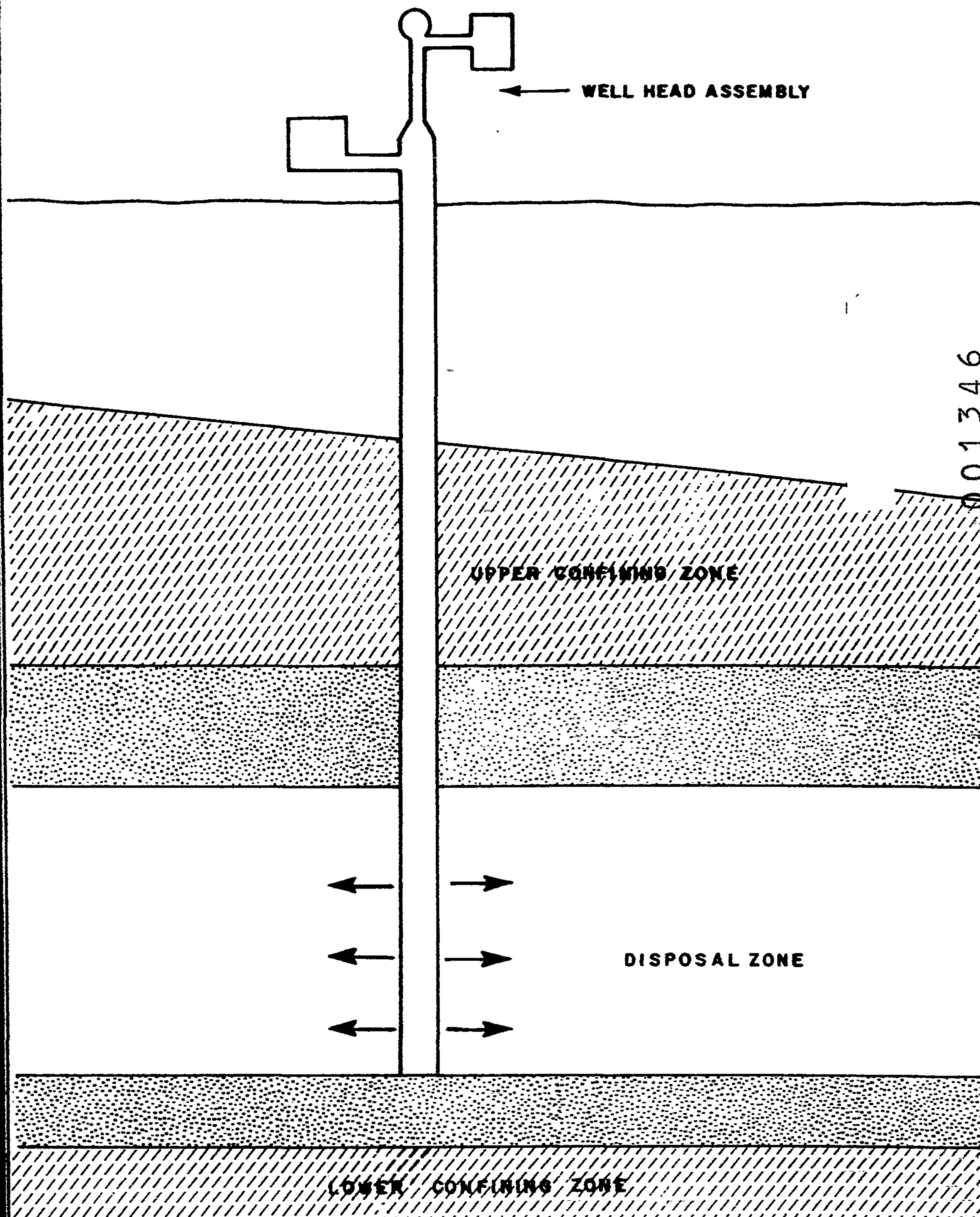
SCALE IN FEET




SOURCE: DISPOSAL SYSTEMS, INC., 1987.

LEGEND

- CLAY
- SHALE

FIGURE 4-8

TYPICAL OFF-SITE INJECTION WELL

NOT TO SCALE

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This alternative would not destroy the TCE but would provide measures for permanent isolation and containment of the contaminated groundwater off-site. The treatment period length for this alternative is governed by the time required to pump the water with the on-site recovery wells. Volatilization of TCE from the tanks to the atmosphere would be prevented by utilizing a closed pumping and storage system.

## 4.4 GROUNDWATER ALTERNATIVE 3 - COLLECTION, ON-SITE CARBON ADSORPTION, AND DISCHARGE

The Activated Carbon alternative will treat the contaminated groundwater at the site using the process described in Section 3 and the recovery system described in Section 4.2. The withdrawal wells at the site would feed a storage tank that would be fitted with an outflow valve near the top of the tank. This would allow for settling of solids and a retention period for the influent water. This tank would also function as an equalization tank to keep flow to the treatment system constant. Figure 4-6 shows a diagram of the typical storage tank. The water would then be piped from the storage tank to the carbon adsorption system (see Figure 4-9 for configuration on-site).

The downflow fixed bed granular activated carbon adsorption system with two beds and off-site regeneration has been chosen based on cost and applicability to the site. The water would flow by gravity down through the column, and the TCE would bind to adsorption sites on the activated carbon. Once the sites became filled with contaminant, it would be necessary to replace or regenerate the carbon. Figure 4-10 shows a schematic for the column. The treated water would then be piped to a second storage tank where it would be tested for TCE concentration.





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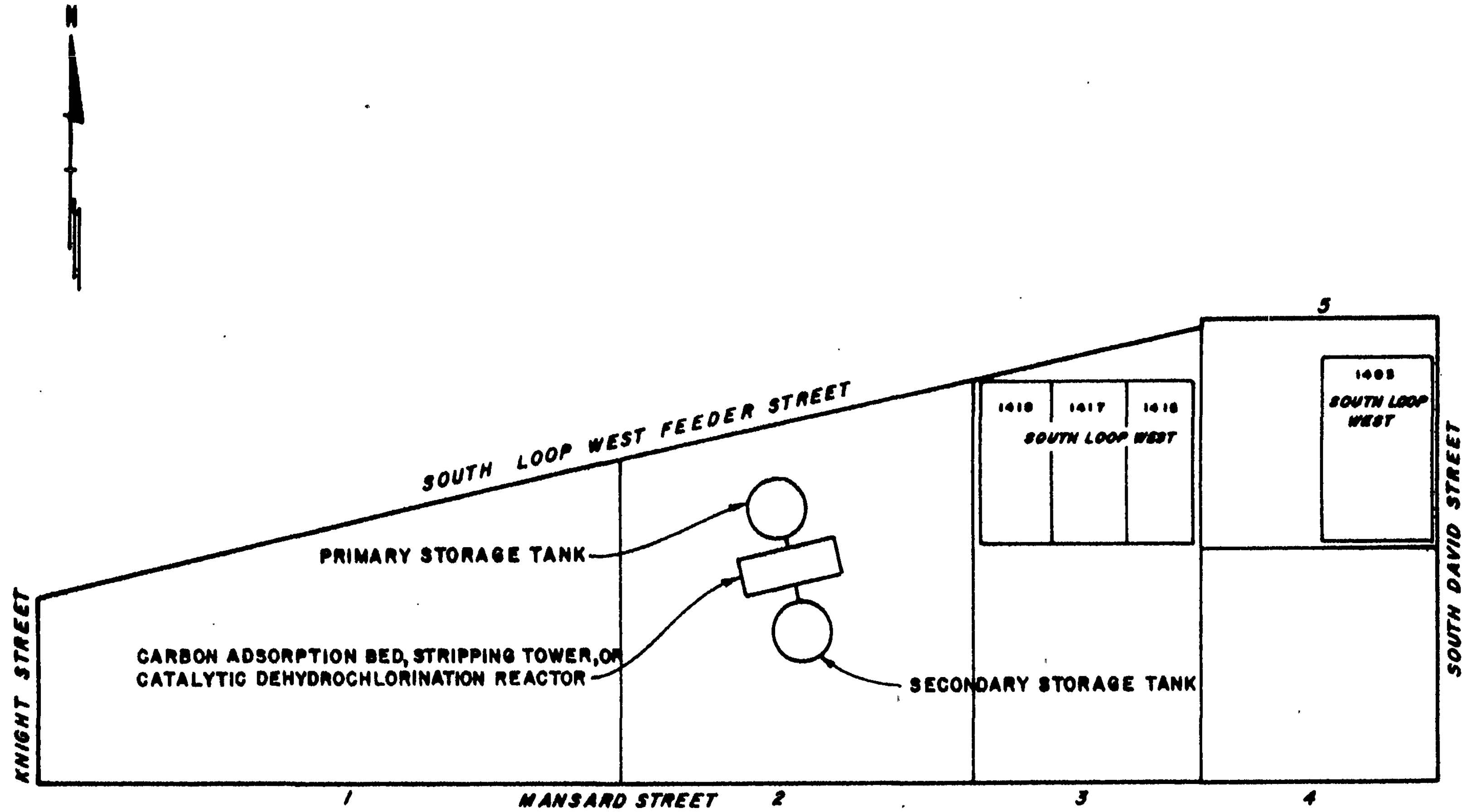


FIGURE 4-9

PROPOSED STAGING AREA FOR ALTERNATIVES 3,4,11

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SCALE IN FEET



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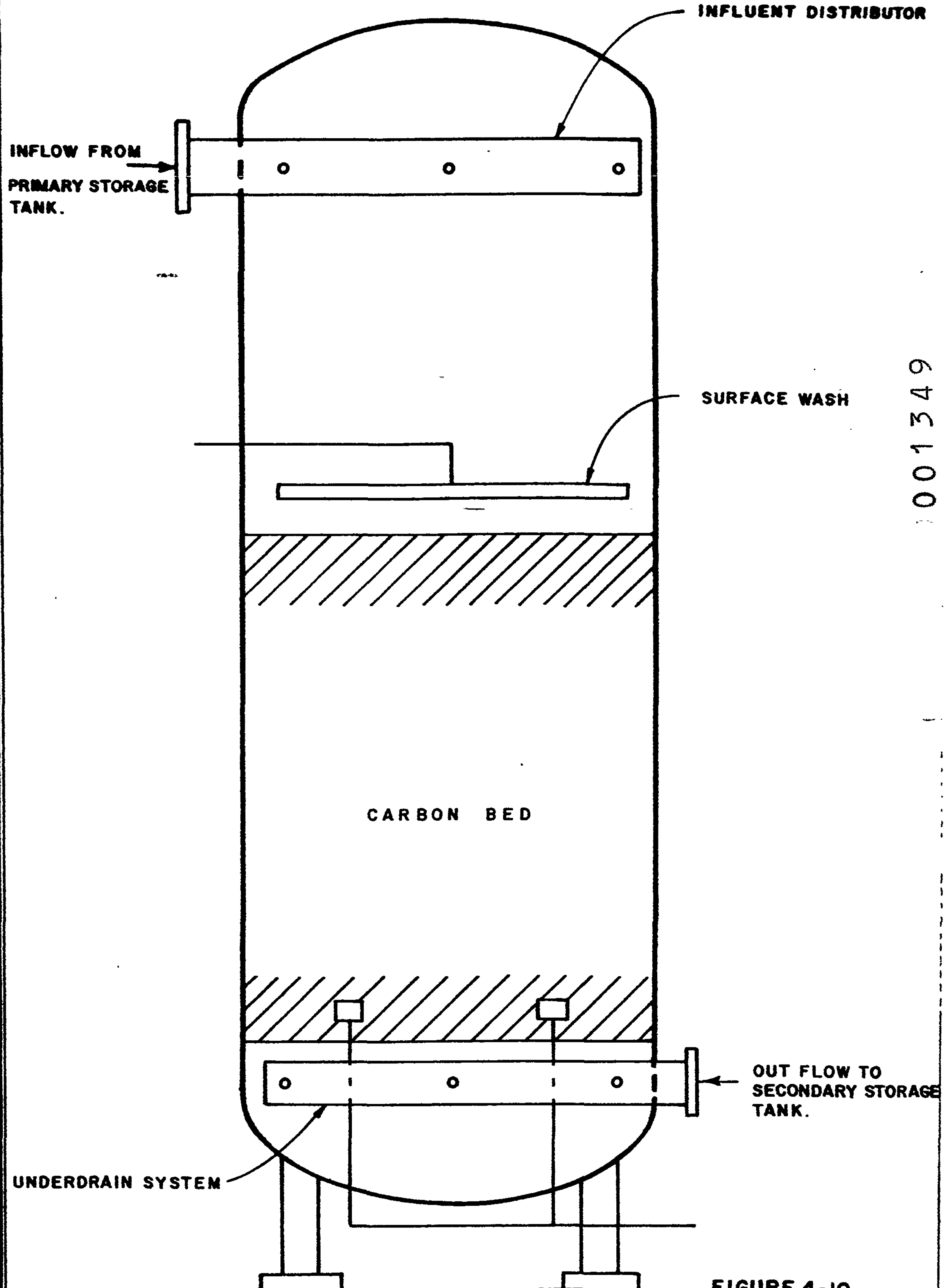


FIGURE 4-10

SOURCE: REYNOLDS, 1982

TYPICAL CARBON ADSORPTION COLUMN

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If the levels were below the discharge criterion, the water would be discharged using one of the options listed in a later section. If the concentration were above the criterion, the water would be run through the secondary carbon bed for polishing. The spent carbon from the adsorption system would be shipped off-site for regeneration or disposal. The settled solids in the primary storage tank would be periodically cleaned out, tested, and disposed appropriately. The testing may be used to delist the wastes so that they may be disposed at a debris landfill.

A treatability study will be required to select the carbon and design the treatment system. However, it is a routine study and easily done.

The site would require monitoring as described in Section 4.3. Upon completion of the treatment, the equipment used for remediation at the site would be decontaminated in accordance with EPA regulations. This includes: the storage tanks, the well casings, the equipment used in the carbon column, and all the piping associated with the recovery and treatment system.

This alternative would not destroy the TCE but would remove the contaminants from the groundwater and concentrate them on the activated carbon. The disposal of the TCE is facilitated by this concentration and removal from the site. The treatment period length for this alternative is governed by the time required to pump the water with on-site recovery wells.

## 4.5 GROUNDWATER ALTERNATIVE 4 - COLLECTION, ON-SITE STRIPPING, AND DISCHARGE

The Air Stripping alternative will treat the contaminated groundwater at the site using the process described in Section 3 and the recovery system described in Section 4.2. The withdrawal wells at the site would feed a storage tank that would be fitted with an outflow valve the tank. This would allow for settling of solids and a retention period for the influent water. Figure 4-6 shows a diagram of a typical storage tank. The water would then be piped from the tank to the air stripping system (see Figure 4-9 for configuration on-site).

The countercurrent packed tower configuration has been chosen for its effectiveness and adaptability. Figure 4-11 shows the air-stripping tower schematic. The water would be collected in a basin at the bottom of the tower and run to a secondary storage tank. The contaminated air discharged from the top of the tower may require secondary treatment. A granular activated carbon adsorption column will be assumed for treatment of these air emissions. The water in the secondary storage tank would be tested for TCE contamination, and if the TCE levels were less than the discharge criterion, the water would be discharged using one of the discharge options described in a following section. If the concentration were above the discharge criterion, the water would be run through the treatment system again. The spent carbon from the air treatment adsorption system would be shipped off-site for regeneration or disposal and would be the responsibility of the vendor. The solids in the primary storage tank would be periodically cleaned out, drummed, tested, and disposed appropriately.

A treatability study will be required to provide design parameters for the stripping tower. However, it is a routine study.

The site would require monitoring as described in Section 4.3. Upon completion of the treatment, the equipment used for remediation at the site would be decontaminated in accordance with EPA regulations. This includes: the storage tanks, the well casings, the equipment used in the stripping tower, the equipment used in the carbon column, and all the piping associated with the recovery and treatment system.

This alternative would not destroy the TCE, but would dilute the contaminants initially in the outflow air, and ultimately concentrate them on the activated carbon in the secondary air treatment unit. The treatment period length for this alternative is governed by the time required to pump the water with the in-site recovery wells.





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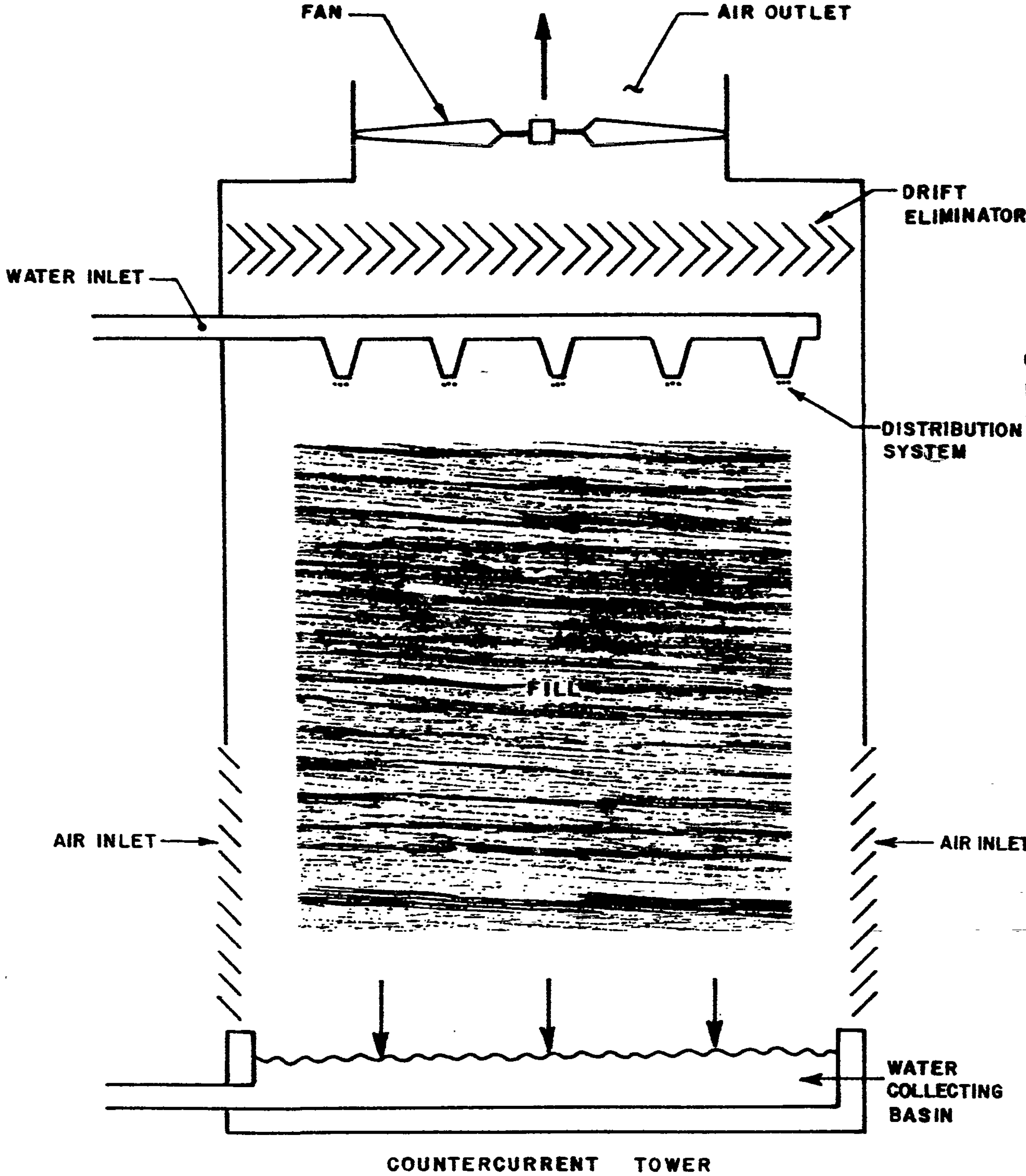


SOURCE: U.S. EPA, 1983.

FIGURE 4-11

AIR - STRIPPING TOWER SCHEMATIC
NOT TO SCALE

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## 4.6 GROUNDWATER ALTERNATIVE 10 - COLLECTION, ON-SITE CATALYTIC DEHYDROCHLORINATION, AND DISCHARGE

The Catalytic Dehydrochlorination alternative will treat the contaminated groundwater at the site using the process described in Section 3 and the recovery system described in Section 4.2. The recovery system at the site would feed a storage tank that would be fitted with an outflow valve two-thirds of the way up the tank. This would allow for settling of solids and a retention period for the influent water. This tank would also function as an equalization tank to keep flow to the treatment system constant. Figure 4-6 shows a diagram of a typical storage tank. The water would then be piped from the storage tank to the dehydrochlorination reactor (see Figure 4-9 for configuration on-site).

A batch dehydrochlorination reactor with a 600 gallon reaction tank has been chosen for applicability to the size and waste stream parameters (the reactor utilized for PCB soil remediation will likely be used for this alternative also). The cycle period would be roughly 1 hour for the reactor with 20 minutes of actual reaction time per batch. This size reactor would be able to handle flows in the range of 1 to 3 gpm. The residuals from this reaction would include off-gases and brine, both of which would probably require additional treatment or disposal. A carbon adsorption column will be assumed for the treatment of the gases, and the brine will be stored and shipped off-site for disposal via deep well injection. The treated water would then be piped to a second storage tank where it would be tested for TCE contamination and process by-products. If the levels were less than the discharge criterion, the water would be discharged using one of the discharge options. If the concentration were above the discharge criterion, the water would be run through the system again. The spent carbon from the adsorption system would be shipped off-site for regeneration or disposal. The solids in the primary storage tank would be periodically cleaned out, tested, and shipped off-site for appropriate disposal.



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The site would require monitoring as described in Section 4.3. A treatability study would be required for this alternative. This study would be performed prior to implementation of this alternative at the site.

Upon completion of the treatment, the equipment used for remediation at the site would be decontaminated in accordance with EPA regulations. This includes: the storage tanks, the well casings, the equipment used in the reactor, the equipment used in the carbon column, and all the piping associated with the recovery and treatment systems.

This alternative would destroy the TCE through chemical reaction. The TCE would be broken down into chlorine salts and elimination products. The treatment period length for this alternative is governed by the time required to pump the water with the on-site recovery wells.

## 4.7 DISCHARGE OPTIONS

### 4.7.1 Discharge Option 1 - Reinjection

This option would entail storing the treated water prior to reinjection into the water-bearing units on-site. This option may increase the recovery rate of the contaminated water if the wells are correctly placed.

### 4.7.2 Discharge Option 2 - Discharge to POTW

This option would entail contacting the POTW near the site, obtaining permission of the City of Houston Public Works Department, and piping the treated water into that system. Regulations require that the discharge is approved by the TWC. The approximate locations of manhole covers leading to the sewer system are shown on Figure 4-12.





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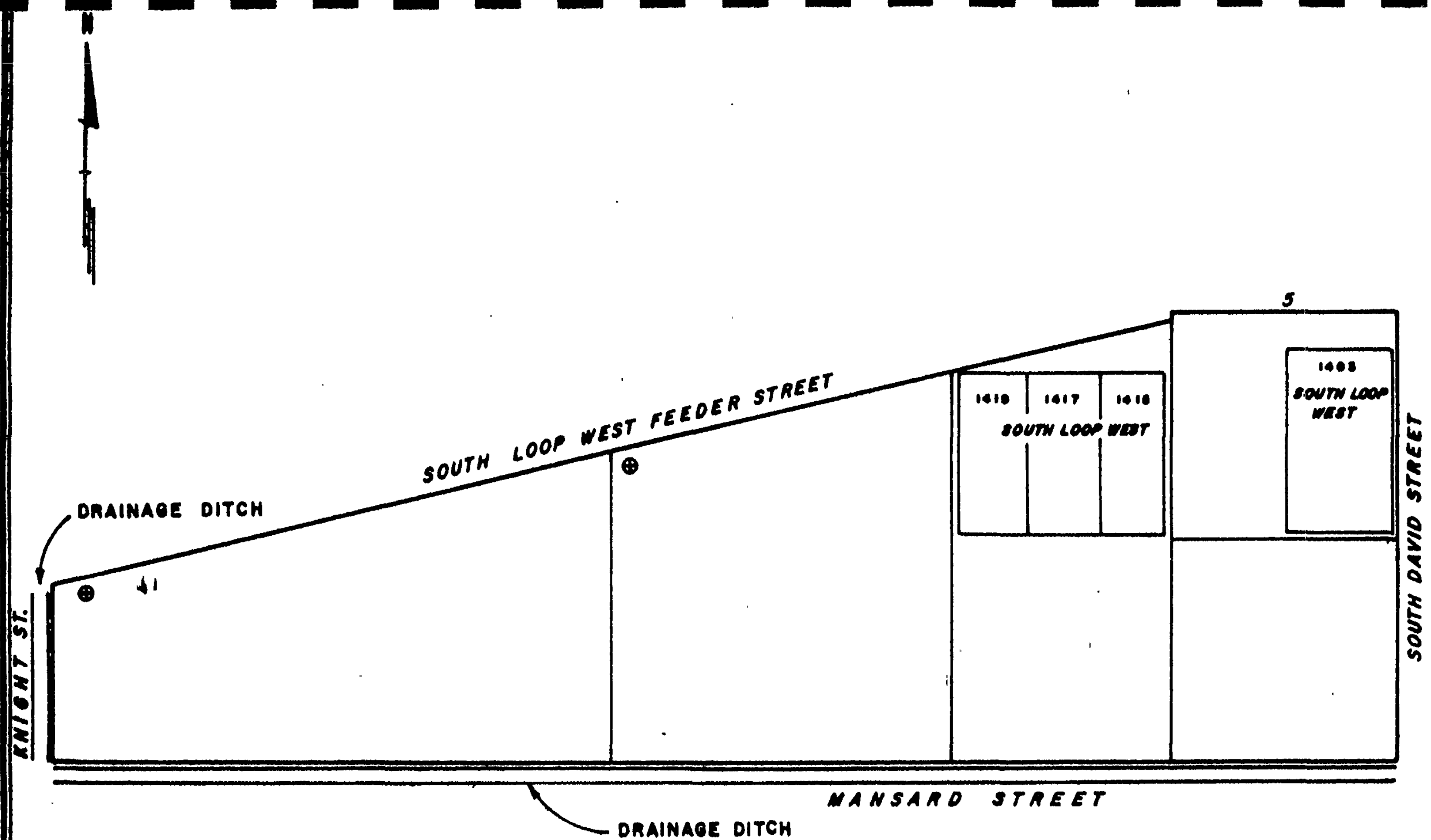


LEGEND

● APPROXIMATE LOCATIONS OF ON-SITE MANHOLE COVERS LEADING TO SANITARY SEWER.

FIGURE 4-12

LOCATION OF DRAINAGE DITCHES AND MANHOLE COVERS.

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SCALE IN FEET

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## SECTION 5

## DETAILED EVALUATION OF ALTERNATIVES

This section provides a detailed evaluation of the alternatives which passed the screening process outlined in Section 3. The evaluation for each alternative will address:

- Technical Analysis;
- Institutional Requirements Analysis;
- Public Health Analysis;
- Environmental Impact Analysis; and
- Cost Analysis.

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This evaluation allows direct comparison between alternatives by various criteria. The technical analyses address the performance, reliability, implementability, and safety of each alternative in greater depth. The institutional analysis discusses each alternative's attainment of applicable or relevant environment and health standards. The public health analysis documents that the remedial alternative minimizes the long-term effects of any residual contamination and protects the public both during and after implementation of the alternative. The environmental impact analysis determines the existence of any adverse environmental effects of the alternatives and methods for mitigating these effects. Finally, the detailed cost analysis encompasses an estimation of capital and operation/maintenance costs for the remedial alternatives, a tabulation of the present worth of the alternative in terms of 1988 dollars, a sensitivity analysis of the cost analysis to changes in key parameters, and a summary of the evaluation data for use in selecting a remedial alternative.

A rating system is used to express the extent to which each alternative meets the criteria for each of the evaluation categories. Alternatives are rated either high, moderate or low.

- A high rating for a particular criterion denotes that the alternative meets or exceeds the remedial objectives;
- A moderate rating denotes that the remedial alternative meets a portion but not all of the remedial objectives; and
- A low rating for a criterion denotes that the remedial alternative does not meet the remedial objectives.

At the end of each evaluation, the two discharge options (reinjection, and discharge to a POTW) are compared using the same criteria for the alternatives.

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## 5.1 TECHNICAL ANALYSIS

This section presents a detailed technical evaluation with respect to the performance, reliability, implementability, and safety of each groundwater alternative. In addition, at the end of the rating section, the two remaining discharge options are also evaluated.

The performance of an alternative is determined by two criteria: the effectiveness of the alternative to perform the intended functions of contaminant diversion, removal, destruction, or treatment and the useful life of the alternative. The effectiveness refers to the degree of protection an alternative affords in preventing or minimizing danger to public health or the environment. The effectiveness of an on-site alternative is affected by locational factors such as aquifer classification, site geology, and floodplain impacts. The useful life of the alternative addresses the deterioration with time of remedial actions such as capping and immobilization; therefore, each alternative should be evaluated in terms of the project life of each of the component technologies.

The reliability of a remedial action may be evaluated in terms of the operation/maintenance requirements plus the demonstrated performance at similar sites. Evaluations of the operation/maintenance requirements for the alternatives should address the availability of labor, materials, and their associated costs, in addition to the frequency and complexity of the operation and maintenance activities. The demonstrated performance evaluation will give preference to those alternatives proven effective under conditions similar to those located at the site. In addition, an estimate of the probability of failure will be made in either quantitative or qualitative terms.

The implementability of an alternative considers issues such as constructability and the time required to achieve the desired level of remedial response. The constructability, or ease or installation of the alternative, is dependent on site conditions and the availability of off-site disposal sites and equipment. Because exposure to hazardous substances should be quickly eliminated, the time to implement an alternative and the time to achieve the desired level of cleanup must be considered. 001358

The fourth issue regarding the technical analysis is safety. Each alternative will be evaluated with regard to long and short-term threats to the safety of nearby communities and environments as well as the safety of the workers during implementation. While each alternative leaves behind residual amounts of TCE (depending on the effectiveness of the recovery system) this residual TCE does not present a significant health risk. Furthermore, for all alternatives not meeting the health-based cleanup levels, the site will receive a five year review, and at that time, groundwater samples will be collected. In addition, the site will be monitored annually for each alternative, with the annual monitoring consisting of the collection of groundwater and soil samples.

The final issue regarding the technical evaluation is an overall technical rating. This evaluation was reached by assigning a value of "1" to a low rating, "2" to a moderate rating, and "3" to a high rating. The separate ratings for performance, reliability, implementability, and safety were then averaged together to obtain a final rating for the technical analysis; this rating is then converted back to a qualitative rating.

A tabulation of the technical analysis ratings is shown in Table 5-1.

### 5.1.1 Groundwater Alternative 1 - No Action

<u>Performance</u> - The no action alternative provides no additional control of contaminant migration and provides no control of exposure of contaminants to potential receptors. The performance rating for the no action alternative is low.

<u>Reliability</u> - This alternative has extensive monitoring activities associated with it. In addition, it has not demonstrated an effective performance. Therefore, the reliability rating for the no action alternative is low.

<u>Implementability</u> - The actions associated with this alternative are easily implemented. Therefore, the implementability rating for the no action alternative is high.

<u>Safety</u> - This alternative does not provide additional safety in the long or short term. The safety rating for the no action alternative is low.

Therefore, the overall technical rating is low.

### 5.1.2 Groundwater Alternative 2 - Collection and Off-Site Deep Well Injection

<u>Performance</u> - The performance of this alternative is governed by its effectiveness and useful life. While deep well injection is an effective method of isolating wastes, this alternative does not provide destruction of the wastes. For this reason, the useful life of the deep well injection alternative may be limited, and the performance rating for Alternative 2 is moderate.

<u>Reliability</u> - Reliability includes issues such as the operation/maintenance requirements and the demonstrated performance of the alternative. Deep well injection facilities accept a wide variety of fluids and have been

TABLE 5-1
SUMMARY OF TECHNICAL FEASIBILITY EVALUATION FOR ALTERNATIVES

| Alternative | Performance | Reliability | Implementability | Safety | Overall Technical Feasibility |
|---|---|---|---|---|---|
| Groundwater | | | | | |
| 1. No Action | Low | Low | High | Low | Low |
| 2. Collection and Off-Site Deep Well Injection | Moderate | Low | Low | Moderate | Moderate |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | Moderate | High | Moderate | High | High |
| 4. Collection, On-Site Stripping, and Discharge | Moderate | High | Moderate | High | High |
| 10.Collection, On-Site Catalytic Dehydrochlorination, and Discharge | Moderate | Low | Moderate | High | Moderate |
| Discharge Options | | | | | |
| 1. Reinjection | High | Moderate | High | High | High |
| 2. Discharge to POTW | Moderate | High | High | High | High |

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successfully used for many years. Deep well injection facilities must meet the requirements for design, construction, monitoring, and maintenance as specified in 40 CFR 144 to 147. Furthermore, these specifications are the responsibility of the vendor operating the well. The withdrawal system shall be operated and maintained on-site until the clean-up criteria are met. Once the groundwater has met the clean-up criteria, no additional operation or maintenance activities will be required on-site. Even so, the reliability of deep well injection is thought to be low because the waste is stored and not treated or destroyed.

Implementability - Implementability considers the availability of off-site disposal sites, the time required to implement an alternative, and the ease of installation. There are three commercial deep well injection facilities in Texas, and the possibility exists that none of them may be able to receive all of the fluid withdrawn over the life of the system. The groundwater clean-up criterion may require years of pumping and years of transporting groundwater on public roads to a disposal facility. Therefore, the implementability of the deep well injection alternative is low.

Safety - Safety issues concern both the long and short term. Long term exposure is alleviated at the site by removal of the contaminants. However, while the contaminants are placed in a confined zone at the injection well facility, they are only stored in the subsurface, and the potential for exposure in the long term exists. Short term exposure to workers will be mitigated through the proper use of safety equipment and adequate decontamination procedures. The safety during transportation of the water (approximately 256 trucks per year) is also a concern.

The safety of the deep well injection alternative is rated moderate, and the overall rating is moderate.

### 5.1.3 Groundwater Alternative 3 - Collection, On-Site Carbon Adsorption, and Discharge

Performance - The performance of an alternative is governed by effectiveness and the useful life of the remedial action. Carbon adsorption effectively and efficiently removes TCE from groundwater at concentrations less





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than one percent (Ehrenfield and Bass, 1983). In addition, systems are purposely designed oversized to protect effluent quality if the influent conditions change. Performance is also affected by biological activity in the carbon and suspended solids in the influent. Finally, once the TCE has been concentrated onto the carbon, the carbon is thermally regenerated off-site and the TCE is destroyed. Because the performance of this process is not always consistent, the performance rating for this alternative is moderate.

Reliability - Carbon adsorption has been proven effective in treating a wide variety of wastes, including TCE. Chemical analyses will be required to determine when the adsorption sites on the carbon have been filled, but a backup column is provided. Therefore, the reliability rating for this alternative is high.

Implementability - Implementability of this alternative is determined by the ease of implementation and the time required for the remedial actions to be completed. Because this alternative will require years of pumping and treating, the implementability rating is moderate.

Safety - Safety issues concern both long and short term public health exposures. Safety equipment and proper waste handling methods increase worker safety for the short term. Carbon adsorption is an acceptable method to effectively concentrate the TCE. Environmental and public health are further protected by incineration of TCE during carbon regeneration. Therefore, the safety rating for this alternative is high.

The overall technical rating for Alternative 3 is high.

### 5.1.4 Groundwater Alternative 4 - Collection, On-Site Stripping and Discharge

Performance - The performance of an alternative is determined by the effectiveness and useful life of the alternative. Air-stripping has consistently been shown to effectively remove volatile organics from groundwater. Furthermore, once the TCE has been removed from the groundwater, the useful life of the alternative is almost infinite. However, air stripping either releases the TCE to the atmosphere, or the TCE is collected from the air and concentrated onto carbon, which is later regenerated or disposed. A variety of factors affect the performance of this alternative, including pumping rate through tower, climate, air flow rate, and packing type. Because the performance is not always consistent, the performance rating for the stripping alternative is moderate.

<u>Reliability</u> - Reliability ratings depend on the operation/maintenance of the alternative and its proven performance. Operation of the recovery system will require years to remove the TCE plume from the subsurface. Maintenance activities for air-stripping equipment are generally few, with the exception of replacing spent carbon when it is used to clean air emissions. Stripping has shown proven performance over many years under a variety of conditions. Therefore, the reliability rating for Alternative 4 is high. 001363

<u>Implementability</u> - Implementability is determined by the constructability and the time required for implementation. Because this alternative will require years of pumping and treating, the implementability rating is moderate.

<u>Safety</u> - Safety issues address both long and short term safety of potentially exposed populations. Short term safety is ensured through the use of safety equipment, including respirators, gloves, and protective clothing. Long term safety is also protected through the removal of TCE from the groundwater. Public safety is higher with an activated carbon unit to clean air emissions used in conjunction with the stripper rather than an air stripper used alone. Therefore, Alternative 4 receives a high safety rating.

The overall technical analysis rating for Alternative 4 is high.

### 5.1.5 <u>Groundwater Alternative 10 - Collection, On-Site Catalytic Dehydrochlorination, and Discharge</u>

<u>Performance</u> - The performance of an alternative encompasses the effectiveness and useful life of the remedial actions. The effectiveness of the

process varies for different compounds and will be governed by the ability of the withdrawal system to recover the TCE plume. In addition, a treatability study is recommended prior to full-scale implementation. The useful life of this alternative is quite long-lasting because dehydrochlorination destroys the TCE.

Because the effectiveness of this alternative is limited by the operation of the recovery system, this alternative receives a moderate rating for performance.

**Reliability** - Reliability includes issues of operation/maintenance requirements and demonstrated performance of the remedial activities. Operation and maintenance activities during implementation may be shared with the PCB remediation efforts, resulting in a lessened overall level of effort. Operation and maintenance activities after remediation will also be minimized because the method destroys the TCE. However, the demonstrated performance has not been documented, and toxicity testing of the process by-products is recommended prior to implementation. Therefore, the reliability rating for Alternative 10 is low.

**Implementability** - Implementability of an alternative is determined by the ease of construction and the time required to effect a complete remediation. The equipment required for this alternative may already be in place for the PCB remediation. Only the recovery system requires installation. The time required to complete the remediation is governed by the recovery rate of the withdrawal system. Because the alternative will require years of pumping and treating, this alternative receives a moderate rating for implementability.

**Safety** - Safety covers both short and long term issues. Short term safety is protected through the use of safety equipment and proper waste handling procedures. Long term safety is also protected because dehydrochlorination destroys the TCE.

The safety rating for Alternative 10 is high and the overall technical evaluation receives a moderate rating.





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### 5.1.6 Discharge Option 1 - Reinjection On-Site

Performance - Reinjection of treated water into the uppermost water-bearing formation at the site is an effective option and may aid in plume recovery. Therefore, this option receives a high performance rating.

Reliability - This option will require some operation/maintenance activities on the pumps and generators; in addition, injected water will require periodic sampling. Therefore, this option receives a moderate reliability rating.

Implementability - This option is readily implemented on-site and wells can be easily screened at the same depth as the recovery wells. Therefore, this option receives a high implementability rating.

Safety - The injected water has been treated to required clean-up levels; therefore, no long or short-term safety problems exist. Therefore, this option receives a high safety rating.

The overall technical feasibility rating is high.

### 5.1.7 Discharge Option 2 - Discharge to POTW

Performance - Discharge of treated water to a POTW is an effective option as long as the water leaving the site after treatment does not require the additional TCE removal at the POTW. As specified in 40 CFR 403, Subpart N, it will have to be shown that TCE does not pass through the POTW. Therefore, this option receives a moderate performance rating.

Reliability - This option will require almost no operation/maintenance activities; however, periodic sampling and analyses of the effluent will be required. In addition, this option is a proven method of discharge of treated water. The reliability rating for this option is high.





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**Implementability** - This option is readily constructed but requires the permission of the City of Houston Public Works Department and the TWC. Discharge limits are set on a case by case basis. In addition, the implementation time is not constrained. Thus, the implementability rating is high.

**Safety** - The discharged water has been treated to the required clean-up levels; therefore, no long or short-term safety problems exist. Thus the safety rating is high.

The overall technical feasibility rating is high.

## 5.2 INSTITUTIONAL ANALYSIS

This section presents an institutional analysis for each alternative based on one category: conformance of the alternative with applicable or relevant and appropriate requirements (ARARs).

EPA policy is to comply to the extent possible with applicable or relevant environmental and public health standards when implementing CERCLA remedial actions, and primary consideration will be given to the alternative meeting or exceeding these standards. However, additional regulations, advisories, and guidance may also be considered in developing these remedies. Furthermore, SARA states a preference for remedies that permanently and significantly reduce the mobility, toxicity, or volume of hazardous material at a Superfund site (Section 121 (b)(1)) to the extent practicable.

The following list details additional regulations pertinent to the implementation of remedial actions at the ITS site.

1. Resource Conservation and Recovery Act (RCRA) (42 USC 6901) - enacted to regulate the management of hazardous waste and its generation, transport, treatment, storage and disposal.

2. Clean Water Act (CWA) (33 USC 1251) - enacted to restore the chemical, physical, and biological integrity of the nation's waters.

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a) National Pollutant Discharge Elimination System (NPDES) (40 CFR 122) - governs point source releases to surface water bodies.

3. Clean Air Act (CAA) (42 USC 7401) - enacted to protect and enhance the quality of the nation's air.

a) Texas Clean Air Act (TCAA) (Proposed Section 118 of Regulation VI, Texas Air Control Board Regulations) - regulates the emissions from facilities that emit various compounds, including TCE. Emissions, including fugitives, may not exceed 5 tons/year and may not exceed E where E equals the maximum hourly emission rate not to exceed 6 pounds/hours. E is based on the equation E = L/K, where L is a contaminant-specific value listed in the proposed regulation and K is a value also listed in the proposed regulations based on distance from the nearest off-site receptor. For ITS, L = 135 mg/$m^3$ and K = 200 for a maximum hourly emission of 0.7 mg/$m^3$.

4. Safe Drinking Water Act (SDWA) (40 CFR 141) - enacted to protect public health by limiting contaminant concentrations present in public drinking water supplies.

a) Underground Injection Control (UIC) (40 CFR 146) - governs the use of injection wells for liquid disposal.

b) Federal Register (132:0130) - set the recommended maximum contaminant level (RMCL) for TCE at zero in Subpart F, Section 141.50. However, since this value is not attainable, the maximum contaminant level (MCL) was set at 0.005 mg/L TCE (5 ug/L or 5 ppb).

5. Occupational Safety and Health Act (OSHA) - emphasizes the need for standards to protect the health and safety of workers exposed to potential hazards at their workplace and established worker exposure limits at 100 ppm TCE with a peak concentration of 150 ppm TCE.

6. Department of Transportation (DOT) Shipping Regulations - specify that hazardous materials must be classified, packaged, marked, labelled, and shipped according to specifications listed in 49 CFR 172.

7. The American Conference of Governmental Industrial Hygienists (ACGIH), 1977 - on the recommendation of the National Institute for Occupational Safety and Health (NIOSH) established worker exposure limits at 100 ppm TCE with a peak concentration of 150 ppm TCE. In addition, set the maximum allowable concentration at 200 ppm provided that the TLV does not exceed 100 ppm. Also set the acceptable maximum peak above the maximum concentration at 300 ppm for a maximum cumulative exposure of five minutes in any two hour period.

8. Pretreatment Regulations for Existing and New Sources of Pollution (40 CFR 403, Subpart N) - regulates quality of water discharged to POTWs.

9. U.S. EPA Groundwater Protection Standard (Policy Statement - August, 1984) - identifies groundwater quality to be attained during remediation to be based upon use of water and aquifer characteristics.

10. National Environmental Policy Act (NEPA), Section 102 (2)(c) - exempts CERCLA remedial actions from preparing an environmental impact statement (EIS).

Each of the remedial alternatives is evaluated with respect to attaining the requirements of pertinent federal, state, and local regulations. A low rating designates no compliance with pertinent laws, a moderate rating indicates compliance with many of the applicable laws, and a high rating indicates complete compliance with the applicable laws. The overall institutional requirements rating then reiterates the results of conformance with ARARs evaluation. The institutional evaluation ratings are listed in Table 5-2.

### 5.2.1 Groundwater Alternative 1 - No Action

No attempt is made to comply with regulations with the no action alternative. In fact, with this type of remedial action, the site results in continuous exposure to the site hazards and could generate off-site contamination in excess of regulatory limits through the actions of contaminant transport caused by horizontal and vertical migration and dispersion.

Conformance with ARARs - The no action alternative does not conform with certain ARARs. This alternative does not meet specifications of CERCLA, as amended by SARA (Section 121 (b)(1)), by not permanently and significantly reducing the mobility, toxicity, or volume of hazardous substances, pollutants, and contaminants. In addition, this alternative does not meet the enforceable drinking water standard of 5 ppb TCE set forth by the EPA.





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TABLE 5-2
SUMMARY OF INSTITUTIONAL REQUIREMENTS EVALUATION

| Alternative | Conformance with ARARs | Overall Institutional Requirements Rating |
|---|---|---|
| Groundwater | | |
| 1. No Action | Low | Low |
| 2. Collection and Off-Site Deep Well Injection | Moderate | Moderate |
| 3. Collection, Off-Site Carbon Adsorption, and Discharge | High | High |
| 4. Collection, On-Site Stripping and Discharge | High | High |
| 10. Collection, On-Site Catalytic Dehydrochlorination, and Discharge | High | High |
| Discharge Options | | |
| 1. Reinjection | High | High |
| 2. Discharge to POTW | High | High |

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The conformance of the no action alternative to ARARs is low and, therefore, the overall institutional requirement is rated low.

### 5.2.2 Groundwater Alternative 2 - Collection and Off-Site Deep Well Injection

Conformance with ARARs - The off-site deep well injection alternative demonstrates positive conformance with the various ARARs. This alternative does not comply with Section 121(b)(1) of CERCLA by not permanently reducing the volume or toxicity of the TCE. However, deep well injection does immobilize the contaminants by isolating them deep in the subsurface in confined formations. This alternative will fulfill the requirements of Underground Injection Control by utilizing only a properly permitted deep well injection facility. While remediation activities may result in exceeding OSHA and ACGIH air exposure limits to workers on-site, the use of safety equipment will reduce that exposure. Following, DOT specifications and using properly licensed carriers will ensure adherence to DOT shipping regulations. Finally, depending on the effectiveness of the recovery system, the 5 ppb MCL for TCE will be achieved to reduce the risk of cancer and other adverse health effects.

For these reasons, the conformance of this alternative to ARARs is moderate and, therefore, the overall institutional rating is moderate.

### 5.2.3 Groundwater Alternative 3 - Collection, On-Site Carbon Adsorption, and Discharge

Conformance with ARARS - This alternative demonstrates conformance with the various ARARs. This alternative complies with Section 121 (b)(1) of CERCLA by reducing the volume of hazardous material. Effluent quality will meet requirements of NPDES with the use of carbon adsorption. Because the treatment system will be totally enclosed, worker air standards as specified by OSHA and ACGIH should not be exceeded; however, the use of safety equipment will further protect worker health. Depending on the effectiveness of the recovery system, the 5 ppb MCL for TCE will be met to reduce the risk of cancer and other adverse effects.





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This alternative conforms to the applicable ARARs; therefore, the carbon adsorption alternative receives a high rating for conformance with ARARs and for the overall institutional requirements rating.

### 5.2.4 Groundwater Alternative 4 - Collection, On-Site Stripping, and Discharge

**Conformance with ARARs** - The on-site stripping alternative conforms with the ARARs. First, this alternative complies with Section 121 (b) (1) of CERCLA by reducing the volume of the wastes when they are concentrated from air stripping emissions to activated carbon. Any discharge water allowed with this alternative will meet the specifications of an NPDES permit or other applicable permit. Air cleaning equipment will ensure that specifications of the CAA and the TCAA are met. Depending on the effectiveness of the recovery system, this alternative meets the MCL for TCE as specified in the Safe Drinking Water Act for all groundwater removed from the aquifers. While OSHA and ACGIH air quality standards will not be exceeded for even short periods of time during remediation, the use of safety equipment will ensure worker safety.

Because this alternative demonstrates conformance with the ARARs, the institutional requirements rating is high.

### 5.2.5 Groundwater Alternative 10 - Collection, On-Site Catalytic Dehydrochlorination, and Discharge

**Conformance with ARARs** - The catalytic dehydrochlorination alternative conforms with most of the ARARs. Foremost, this alternative conforms with Section 121 (b)(1) of CERCLA by destroying the TCE. Any water discharges from the site shall meet specifications of an NPDES permit or other applicable permit. All groundwater removed from the aquifers shall be treated to attain the MCL for TCE specified in the Federal Register under the SDWA. Worker's health will be protected from any air emissions greater than the limits set by OSHA and ACGIH through the use of safety equipment. In addition, the emission limits set by the TCAA will be met.

Since this alternative conforms with the appropriate ARARs, it receives a high rating for both conformance with ARARs and institutional requirements rating.

5.2.6 <u>Discharge Option 1 - Reinjection On-Site</u>

<u>**Conformance with ARARs**</u> - This option conforms to the ARARs regarding reinjection of water into the subsurface. The water will be treated to drinking water standards prior to injection. Therefore, the reinjection discharge option receives a high rating for conformance with ARARs.

The overall institutional requirements rating is high.

5.2.7 <u>Discharge Option 2 - Discharge to POTW</u>

<u>**Conformance with ARARs**</u> - This option conforms to the ARARs regarding a point source discharge to a POTW, including City of Houston regulations and Pretreatment Regulations for Existing and New Sources for Pollution. In addition, the POTW must meet the requirements of an NPDES permit.

Thus, Discharge Option 2 receives a high rating for conformance with ARARs and for the overall institutional requirements rating.

5.3 <u>PUBLIC HEALTH ANALYSIS</u>

This section provides information on the degree to which each remedial alternative protects public health, welfare, and the environment both during and after implementation of the alternative. The public health evaluations consider:

- The minimization or prevention of contaminant releases both during and after remedial activities;
- Nearby population exposure levels during remedial activities; and
- Population exposures after remedial activities.

Similar to the evaluations using previous criteria, this evaluation was made quantitative by utilizing the terms "low", "moderate", and "high" to denote minimal, moderate, and high protection (respectively) of nearby populations from threats posed by each particular alternative. Finally, a summary public health analysis rating is obtained by assigning numerical values to the individual ratings and averaging them. The public health evaluations are depicted in Table 5-3.

Because the recovery well system used with all but the no action alternative cannot remove all of the TCE in the soil, none of the alternatives is highly effective at "minimizing or preventing contaminant releases". However, a properly designed recovery system may be able to remove TCE in the groundwater to the 5 ppb cleanup criterion. Because of the potential for future contaminant release, moderate will be the best possible rating for this criterion.

### 5.3.1 Groundwater Alternative 1 - No Action

<u>Minimization or Prevention of Contaminant Release</u> - The no action alternative does not prevent or minimize contaminant releases to lower aquifers or shallow wells. Therefore, the no action alternative receives a low rating for this criterion.

<u>Exposure Levels During Remediation</u> - Since the no action alternative requires no remedial work to be done on-site, exposure levels to nearby populations should remain low. However, this alternative receives a low rating for this criterion because it provides no control action on the contaminated areas.

<u>Exposure Levels After Remediation</u> - Because site conditions remain unchanged by this alternative, exposure levels are also unchanged. Therefore, the no action alternative receives a low rating for this criterion.

The overall public health evaluation is low for the no action alternative.





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TABLE 5-3
SUMMARY OF PUBLIC HEALTH EVALUATIONS

| Alternative | Minimization or Prevention of Contaminant Release | Protection from Exposure During Remediation | Protection from Exposure After Remediation | Overall Public Health Evaluation |
|---|---|---|---|---|
| Groundwater | | | | |
| 1. No Action | Low | Low | Low | Low |
| 2. Collection and Off-Site Deep Well Injection | Moderate | High | High | High |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | Moderate | High | High | High |
| 4. Collection, On-Site Stripping, and Discharge | Moderate | High | High | High |
| 10. Collection, On-Site Catalytic Dehydrochlorination, and Discharge | Moderate | High | High | High |
| Discharge Options | | | | |
| 1. Reinjection | N/A | N/A | N/A | N/A |
| 2. Discharge to POTW | N/A | N/A | N/A | N/A |

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5.3.2 Groundwater Alternative 2 - Collection and Off-Site Deep Well Injection

Minimization or Prevention of Contaminant Release - The off-site deep well injection alternative results in a minimization of contaminant release by removing the contamination to an off-site injection facility. However, the possibility of the deep well failing at some future date does exist and the recovery system cannot remove all of the TCE, resulting in the possibility of future contaminant release. Therefore, this alternative receives a moderate rating for minimizing or preventing contaminant release.

Exposure Levels During Remediation - The configuration of the pumps, piping and tanks used for this alternative will be designed to minimize TCE releases to the atmosphere. In addition, safety equipment will protect the workers on-site. For these reasons, this alternative receives a high rating for this criterion.

Exposure Levels After Remediation - The deep well injection alternative provides for greatly reduced potential exposure levels after remediation. Thus, Alternative 2 receives a high rating for this criterion.

The overall public health criterion for the off-site deep well injection alternative is high.

5.3.3 Groundwater Alternative 3 - Collection, On-Site Carbon Adsorption, and Discharge

Minimization or Prevention or Contaminant Release - Alternative 3 causes a minimization of future contaminant release. Because the contaminated groundwater is removed and treated, further contaminant release from the site is greatly minimized. If the spent carbon is regenerated, the possibility of release of TCE to the environment is low. However, because the recovery well system cannot remove all of the TCE, resulting in the possibility of future contaminant release, this alternative receives a moderate rating.

<u>Exposure Levels During Remediation</u> - Because the process equipment will be configured to minimize TCE released to the environment and safety equipment will be used by workers, on-site exposure levels are minimized. Thus, this alternative receives a high rating for this criterion.

<u>Exposure Levels After Remediation</u> - To meet the clean-up criterion, this alternative provides for greatly reduced potential exposure levels once remediation has been completed. The rating for this criterion is then high.

The overall public health evaluation of Alternative 3 is high.

### 5.3.4 Groundwater Alternative 4 - Collection, On-Site Stripping, and Discharge

<u>Minimization or Prevention of Contaminant Release</u> - The air stripping alternative effectively removes TCE from the groundwater that is withdrawn from the aquifers and treated. However, the treatment just removes the contaminants from the water and releases them to the atmosphere. Thus, the use of emissions control equipment is recommended to prevent this release. Alternative 4 receives a moderate rating for this criterion because of the potential future contaminant releases that exist due to the inability of the recovery system to remove all of the TCE.

<u>Exposure Levels During Remediation</u> - The remedial activities associated with this alternative exhibit the potential for exposures of the on-site workers and nearby residential populations to TCE. However, emissions control equipment, safety equipment and dilution in the atmosphere negate the potential hazards, and this alternative receives a high rating for this criterion.

<u>Exposure Levels After Remediation</u> - The air stripping alternative results in greatly reduced potential exposure levels once remediation has been completed. Therefore, this alternative receives a high rating for mitigating exposure levels after remediation.





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The overall public health evaluation for this alternative is high.

5.3.5 Groundwater Alternative 10 - Collection, On-Site Catalytic Dehydrochlorination, and Discharge

Minimization or Prevention of Contaminant Release - The catalytic dehydrochlorination alternative greatly reduces the potential for contaminant release by destroying the TCE in the treated groundwater. However, this alternative only minimizes potential contaminant release for that groundwater actually withdrawn from the subsurface using the recovery system. Because the recovery system may not be able to remove all of the TCE contamination, this alternative receives a moderate rating for this alternative.

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Exposure Levels During Remediation - Exposure levels during remediation may be minimized by utilizing safety equipment and proper equipment configuration. Thus, Alternative 10 receives a high rating for this criterion.

Exposure Levels After Remediation - Since this alternative destroys TCE, exposure levels after remediation are greatly reduced. For this reason, this alternative receives a high rating for this criterion. In addition, a toxicity test is recommended prior to full scale implementation to ensure that the process by-products will not harm human health or the environment.

A high overall public health evaluation rating is assigned to Alternative 10.

5.3.6 Discharge Option 1 - Reinjection On-Site

Because the water will be treated before discharge, the public health evaluation section is not applicable to this option.

5.3.7 Discharge Option 2 - Discharge to POTW

Because the water will be treated before discharge, the public health evaluation section is not applicable to this option.

## 5.4 ENVIRONMENTAL IMPACTS ANALYSIS

Each remedial alternative will be evaluated for its beneficial and adverse environmental impacts. The beneficial effects evaluation details the final environmental conditions, the improvements in the biological environment, and the improvements in human use of the on-site resources for each alternative. The adverse effects evaluation explores the adverse effects of both the construction/operation activities and the mitigative measures.

As for the other analyses, the environmental impacts analysis encompasses a qualitative evaluation of the alternatives through a scaled rating using "high", "moderate", and "low". A high rating indicates a high beneficial promotion of environmental concerns such as the removal or destruction of contaminants, reduction or contaminant migration, and restoration of original site use. A low rating indicates that the alternative either contributes to or does not mitigate adverse effects at the site. Adverse effects at the ITS site include temporary removal of site vegetation, potential for contaminant migration during construction of the remedial activities, and noise and dust caused by construction equipment. Finally, each alternative is allotted an overall environmental impacts rating that is obtained by assigning a numerical value to the ratings of "high", "moderate", or "low" and averaging the values to obtain a final, overall rating. A summary of the environmental impacts analysis is presented in Table 5-4.

### 5.4.1 Groundwater Alternative 1 - No Action

Beneficial Effects - The no action alternative offers no beneficial effects. TCE will continue to migrate and may contaminate drinking water supplies. Therefore, the no action alternative receives a low rating for beneficial effects.





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TABLE 5-4
SUMMARY OF ENVIRONMENTAL IMPACTS ANALYSIS

| Alternative | Beneficial Effects Rating | Mitigation of Adverse Effects Rating | Overall Environmental Impacts Rating |
|---|---|---|---|
| <u>Groundwater</u> | | | |
| 1. No Action | Low | Low | Low |
| 2. Collection and Off-Site Deep Well Injection | High | Low | Moderate |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | High | Moderate | High |
| 4. Collection, On-Site Stripping, and Discharge | High | Moderate | High |
| 10. Collection, On-Site Catalytic Dehydro-chlorination and Discharge | High | Moderate | High |
| <u>Discharge Options</u> | | | |
| 1. Reinjection | High | High | High |
| 2. Discharge to POTW | High | High | High |

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<u>Adverse Effects</u> - The no action alternative includes no construction or operation measures and provides no mitigative effects. Exposure to and migration of site contamination will continue. Therefore, this alternative acquires a low rating for mitigation of the adverse environmental impacts.

The no action alternative receives an overall environmental impacts rating of low.

### 5.4.2 Groundwater Alternative 2 - Collection and Off-Site Deep Well Injection

<u>Beneficial Effects</u> - The off-site deep well injection alternative results in the withdrawal, deportation, and off-site injection of groundwater contaminated with TCE in excess of 5 ppb. This means greatly improved final environmental conditions on-site while potentially exposed populations are protected from TCE, and the groundwater may be safely used. Therefore, Alternative 2 receives a high rating for beneficial effects.

<u>Adverse Effects</u> - Implementation of this alternative also results in potential adverse effects during the implementation phase. These adverse effects include:

- Grass ripped up and soil rutted from drilling equipment;
- Additional dust, noise, and traffic caused by vacuum trucks and drill rigs; and
- Possible failure of the deep well injection facility at some point in the future.

Most of these adverse effects are temporary construction measures, and the severity may be mitigated by implementing dust and noise control actions and specifying trucking routes. However, the third adverse effect listed above represents a risk to future drinking water supplies. Therefore, this alternative receives a low rating for controlling adverse effects.

The overall environmental impacts rating for Alternative 2 is moderate.



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### 5.4.3 Groundwater Alternative 3 - Collection, On-Site Carbon Adsorption, and Discharge

**Beneficial Effects** - Alternative 3 yields a variety of beneficial effects. Carbon adsorption removes the TCE from contaminated groundwater which reduces the possibility of contaminant migration and restores the groundwater for future use. In addition, this alternative should interfere little with commercial activities on-site. Thus, the carbon adsorption alternative receives a high rating for beneficial effects.

**Adverse Effects** - Alternative 3 results in various temporary adverse effects which may be mitigated through the use of dust, noise, and traffic control measures. Therefore, this alternative receives a moderate rating for reducing adverse environmental effects.

The overall environmental impacts rating for the carbon adsorption alternative is high.

### 5.4.4 Groundwater Alternative 4 - Collection, On-Site Stripping, and Discharge

**Beneficial Effects** - Air stripping provides many beneficial effects. This alternative removes the TCE from the groundwater which reduces future contaminant migration from the site. In addition, the groundwater may then be safely used as a water source. Therefore, this alternative receives a moderate rating for promoting beneficial environmental effects.

**Adverse Effects** - This alternative results in a variety of temporary adverse effects which may be mitigated through the use of dust, noise, and traffic control measures. An additional adverse effect is the possibility of air emissions of TCE (which will be prevented by using a carbon column on the air emissions). Therefore, this alternative receives a moderate rating for reducing adverse environmental impacts.





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The overall environmental effects rating for the air stripping alternative is high.

### 5.4.5 Groundwater Alternative 10 - Collection, On-Site Catalytic Dehydrochlorination, and Discharge

Beneficial Effects - The catalytic dehydrochlorination alternative results in a variety of beneficial effects. Foremost, this alternative has the capability to destroy the TCE in the treated groundwater. This in turn greatly reduces the potential for future contaminant migration. In addition, the remedial activities will not interfere with commercial activities on-site. Consequently, dehydrochlorination receives a high rating for promoting beneficial environmental effects. 001382

Adverse Effects - This alternative exhibits several temporary adverse environmental effects, that may occur during remediation including torn up soil cover, potential for TCE release, and excessive noise, dust, and traffic. Because these adverse effects are only temporary, this alternative receives a moderate rating.

Therefore, the overall environmental impacts rating for the dehydrochlorination alternative is high.

### 5.4.6 Discharge Option 1 - Reinjection On-Site

Beneficial Effects - This option offers the beneficial effect of low cost and easy implementation. Also, this option aids the recovery system by forcing subsurface flow toward the recovery wells (if the injection wells are correctly placed). Therefore, this option receives a high rating for beneficial effects.

Adverse Effects - This option does not create any major adverse environmental effects. Therefore, this option receives a high rating for this criterion.

A high overall environmental effects rating.

### 5.4.7 Discharge Option 2 - Discharge to POTW

**Beneficial Effects** - This discharge option offers the beneficial effect of additional treatment of the treated groundwater at the POTW. Thus, this option receives a high rating for beneficial effects.

**Adverse Effects** - Because this option does not result in any major adverse environmental effects, this option receives a high rating for this criterion.

The overall environmental effects rating for this option is high.

## 5.5 COST ANALYSIS

Cost analysis incorporate three tasks as specified in the EPA Guidance on Feasibility Studies under CERCLA (1985). These are:

- Estimation of Costs;
- Present Worth Analysis; and
- A Sensitivity of Cost to Changes in Key Parameters.

Cost estimates reflect site-specific conditions and include capital costs and operation/maintenance costs for all alternatives. The cost estimates represent a -30% to +50% accuracy, depending on assumptions. Present worth analyses are useful to compare the costs of different alternatives by computing the current value of all costs incurred including those incurred in the present or at some future date. Finally, the cost screening analysis consists of comparing the present worth costs of alternatives with similar environmental, public health, and public welfare benefits to the other alternatives. The cost screening can be used to eliminate those alternatives that offer similar or fewer environmental and public health benefits, with no greater reliability, and at a cost of





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an order of magnitude greater. However, more expensive alternatives offering substantially greater environmental or health benefits will not be eliminated.

Cost estimates are based on the conceptual designs as discussed in Section 4. The estimates for the capital and operation/maintenance costs are expressed in 1988 dollars.

Total capital costs were developed under two categories: direct and indirect costs. Costs for each remedial alternative were derived from literature sources, vendor quotes, and previous studies. Table 5-5 shows a summary of the capital cost breakdowns for each alternative. A more detailed cost breakdown may be found in Appendix C. Direct cost assumptions are listed below:

- The amount of TCE contaminated groundwater at concentrations greater than 5 ppb currently in the uppermost water-bearing unit is approximately 3.2 million gallons;
- Additional water in the sensitivity analyses will be assumed to be withdrawn from the intermediate aquifer. This assumption was made to underscore the fact that water in the intermediate aquifer will require remediation; however, an estimate of the amount of groundwater requiring remediation in that unit cannot be made at this time.
- The recovery system for the uppermost aquifer consists of ten wells on 50-foot centers and is utilized for all "pump and treat" schemes. A recovery system will also be utilized to remediate the intermediate aquifer.
- The recovery system pumps at a cumulative rate of 3500 gallons/day, or 350 gallons/day/well for 10 years.
- The recovery system only withdraws contaminated water from the uppermost aquifer (the sensitivity analysis addresses the case when extra, uncontaminated water is brought to the surface from the intermediate aquifer).
- All alternatives include a capital cost for drilling out and plugging out the abandoned water well described in the RI.



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TABLE 5-5

SUMMARY OF COSTS FOR 4% INTEREST RATE

| Remedial Alternative | Capital Cost | Annual Operation and Maintenance | Present Worth of O & M at 4% for 10 years | Total Present Worth |
|---|---|---|---|---|
| <u>Groundwater</u> | | | | |
| 1. No Action | $ 36,533 | $ 40,375 | $ 327,481 | $ 364,015 |
| 2. Collection and Off-Site Deep Well Injection | 93,737 | 532,137 | 4,316,167 | 4,409,905 |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | 177,940 | 109,137 | 885,214 | 1,063,154 |
| 4. Collection, On-Site Stripping, and Discharge | 158,651 | 61,137 | 495,886 | 654,537 |
| 10. Collection, On-site Catalytic Dehydrochlorination, and Discharge | 406,286 | 674,537 | 5,471,173 | 5,877,460 |
| <u>Discharge Options</u> | | | | |
| 1. Reinjection | 24,588 | 2,763 | 41,873 | 66,462 |
| 2. Discharge to POTW | 4,701 | 25,550 | 207,236 | 211,937 |

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Indirect capital costs include such factors as engineering, design, administration, inspection, contingency, preparation of permits, and shakedown. Indirect capital costs calculations require the following assumptions:

- Contingency allowances were based on 10 percent of the total direct construction cost;

- Engineering and design allowances were also based on 10 percent of the total direct construction cost;

- Administration and inspection expenses were calculated as 4 percent of the total direct construction cost; and

- Permitting costs ranged from 0 to 5 percent of the total direct construction costs, depending on the complexity of the tasks required to meet permit specifications (obtaining the actual permit is not required at Superfund sites).

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Annual operation and maintenance costs for each alternative were based on estimated labor and materials costs in addition to sampling and analysis requirements. Itemized operation and maintenance costs are shown in Appendix C and summarized in Table 5-5. Again, cost estimates were formulated to include ten years of operation of the recovery system.

Annual operation and maintenance costs include:

1) Quarterly water sampling from 20 observation wells;
2) Yearly soil sampling in five boreholes;
3) Sampling of treated water on a weekly basis; and
4) Pump maintenance occurring on one day per month.

A present worth analysis was used to facilitate a cost comparison between alternatives requiring different amounts of operation and maintenance by discounting future costs to a common monetary basis, the present worth. The present worth cost represents the amount of money for the remedial action over its planned life that is invested in the base year and is expended as needed. Thus, the present worth of an alternative is greater at lower interest rates because more money is needed initially at the lower interest rates to finance operation and maintenance costs.

Present worth can be calculated with the following formula:

PW = PWF (O + M) + TCC

where PW = present worth,
PWF = present worth factor based upon a 4 percent interest rate over a period of 10 years and obtained from Grant and Ireson (1964).
O + M = annual operation and maintenance costs, and
TCC = total capital cost.

Even though the PWF is based on an annual interest rate of 4 percent and a ten year remediation period, no inflation factors have been included. The 4 percent interest rate was chosen to yield conservative cost estimates. Furthermore, the EPA Guidance Document (EPA, 1985) prescribes a planned life of a facility for analysis to a minimum of 30 years. Present worth analyses are also shown in detail in Appendix C and are summarized in Table 5-5.

When the present worth analyses were completed, a sensitivity analysis was performed on the costs to evaluate the effects of variations in cost assumptions on the final present worth. The parameters whose values are most unknown or least certain are: the length of the pump period, the number of recovery or injection wells installed, the number of gallons pumped, and the interest rate. Therefore, the sensitivity analysis details the effects of changing these variables on the total present worth for each alternative. In addition to the present worth costs described above for each alternative (Scenario A), the various scenarios studied in the sensitivity analysis were:

- The number of wells in the recovery system increased to 20, but the pumping rate, i.e. the cumulative rate of 3500 gallons/day, remained the same over a 10 year period (Scenario B);
- The number of recovery wells increased to 50, with each well pumping at a rate of 350 gallon/day over a ten year period (Scenario C);
- The number of recovery wells increased to 50, with the cumulative pump rate remaining at 3500 gallons/day for 10 years (Scenario D);
- The operation and maintenance period increased to 20 years (Scenario E);
- The operation and maintenance period decreased to 5 years (Scenario F); and

The sensitivity analysis present worth costs for the alternatives are summarized in Table 5-6 and detailed in Appendix D. While the total present worths vary greatly depending on the particular scenario studied, the relative rankings of the alternatives from highest to lowest costs remain the same except for Scenario C for the alternatives and Scenario D for the discharge options. The typical price ranking, from highest to lowest, is as follows:

- <u>Groundwater Alternatives</u>:
  10. Collection, On-Site Catalytic Dehydrochlorination, and Discharge,
  2. Collection and Off-Site Deep Well Injection,
  3. Collection, On-Site Carbon Adsorption, and Discharge,
  4. Collection, On-Site Stripping, and Discharge,
  1. No Action.

- <u>Discharge Options</u>:
  2. Discharge to POTW,
  1. Reinjection.

The sensitivity analyses seem to show that for the alternatives the total present worth costs are not sensitive to major capital cost increases or to increases in the number of years of remediation or interest rate. However, the total present worth of Alternative 2 is sensitive to an increase in capital costs accompanied by relatively large annual operation and maintenance costs (or in other words, a relatively large amount of water requiring treatment per year).

The discharge options appear to be insensitive to the number of years of remediation or interest rates. Discharge Option 1 does appear to be sensitive to large increases in capital costs when accompanied by rather low annual operation and maintenance costs.

TABLE 5-6

SENSITIVITY ANALYSIS OF ALTERNATIVES - PRESENT WORTH COSTS

| Alternative | Scenario A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| **Groundwater** | | | | | | | |
| 1. No Action | $ 364,015 | $ 364,015 | $ 364,015 | $ 364,015 | $ 585,229 | $ 216,283 | $ 284,597 |
| 2. Collection and Off-Site Deep Well Injection | 4,409,905 | 4,454,035 | 20,464,672 | 4,609,382 | 7,325,486 | 2,462,813 | 3,363,190 |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | 1,063,154 | 1,110,590 | 3,107,188 | 1,275,922 | 1,661,119 | 663,820 | 848,481 |
| 4. Collection, On-Site Stripping, and Discharge | 654,537 | 701,975 | 1,419,477 | 867,305 | 989,510 | 430,835 | 534,280 |
| 10. Collection, On-Site Catalytic Dehydrochlor-ation, and Discharge | 5,877,460 | 5,922,098 | 13,423,314 | 6,078,978 | 9,573,251 | 3,409,327 | 4,550,644 |
| **Discharge Options** | | | | | | | |
| 1. Reinjection | 66,462 | 109,210 | 261,167 | 261,167 | 94,747 | 47,572 | 56,307 |
| 2. Discharge to POTW | 211,937 | 211,937 | 1,040,881 | 211,937 | 351,926 | 118,450 | 161,680 |
| **Ranking** | | | | | | | |
| Groundwater Alternative | 10,2,3,4,1 | 10,2,3,4,1 | 2,10,3,4,1 | 10,2,3,4,1 | 10,2,3,4,1 | 10,2,3,4,1 | 10,2,3,4,1 |
| Discharge Option | 2,1 | 2,1 | 2,1 | 1,2 | 2,1 | 2,1 | 2,1 |

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Considering failure costs was also required. Failure costs are those costs incurred by implementing a new alternative when the original alternative has failed to achieve the remedial objectives. The innovative alternatives are more likely to fail than the more proven alternatives. Treatability studies have been recommended for the innovative alternatives, and the likelihood of failure may be determined during these tests. Because the treatability study in no way worsens the contamination situation, the failure cost for an alternative will consist of the treatability study costs for an innovative alternative plus the cost of implementing one of the more traditional, proven methods of TCE remediation. The alternative costs are presented in Appendix C.

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## 5.6 SUMMARY OF ALTERNATIVES

This section presents a summary of the detailed evaluation of the alternatives, shown in Table 5-7. Also presented are the major advantages and disadvantages of each alternative.

### 5.6.1 Groundwater Alternative 1 - No Action

**Advantages** - The main advantage of Alternative 1 is the low cost. This alternative requires no remedial action. Only environmental monitoring will take place at the site.

**Disadvantages** - The disadvantages of this alternative include the continued health risks to receptors contacting contaminants from the site, noncompliance with ARARs, and contaminant migration.

### 5.6.2 Groundwater Alternative 2 - Collection and Deep Well Injection

**Advantages** - The advantages of the deep well injection alternative includes removal of TCE to prevent future migration from the site and easy implementation.

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TABLE 5-7

SUMMARY OF DETAILED EVALUATIONS FOR FINAL ALTERNATIVES

| Remedial Alternative | Technical Feasibility Analysis | Institutional Requirements Analysis | Public Health Analysis | Environmental Impacts Analysis | Total Present Worth |
|---|---|---|---|---|---|
| <u>Groundwater</u> | | | | | |
| 1. No Action | Low | Low | Low | Low | $ 364,015 |
| 2. Collection and Off-Site Deep Well Injection | Moderate | Moderate | High | Moderate | 4,409,905 |
| 3. Collection, On-Site Carbon Adsorption, and Discharge | High | High | High | High | 1,063,154 |
| 4. Collection, On-Site Stripping, and Discharge | High | High | High | High | 654,537 |
| 10. Collection, On-Site Catalytic Dehydro-chlorination, and Discharge | Moderate | High | High | High | 5,877,460 |
| <u>Discharge Options</u> | | | | | |
| 1. Reinjection | High | High | N/A | High | $ 66,462 |
| 2. Discharge to POTW | High | High | N/A | High | 211,937 |

**Disadvantages** - The disadvantages include a long-term contract with a shipping company, the associated high costs, the potential for the deep well injection facility to fail, and increased traffic resulting in the potential for an accident.

### 5.6.3 Groundwater Alternative 3 - Collection, On-Site Carbon Adsorption, and Discharge

**Advantages** - Advantages of carbon adsorption treatment include effectiveness, attainment of MCL for drinking water, prevention of future contaminant migration, and relatively low cost.

**Disadvantages** - Disadvantages include a relatively high frequency of effluent sampling to detect exhaustion of the primary carbon column and potential need for pretreatment to remove suspended solids.

### 5.6.4 Groundwater Alternative 4 - Collection, On-Site Stripping, and Discharge

**Beneficial Effects** - Beneficial effects of this alternative include:

- Technical feasibility and easy implementation;
- Removing potential for future contamination of the groundwater; and
- Relatively low cost.

**Adverse Effects** - Adverse effects include the potential need for pretreatment and potential release of TCE to the atmosphere.

### 5.6.5 Groundwater Alternative 10 - Collection, On-Site Catalytic Dehydrochlorination, and Discharge

**Beneficial Effects** - Beneficial effects include technical feasibility, protection of groundwater from future contamination, and decreased capital costs as the result of using the same reactor for the PCB remediation.





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**Adverse Effects** - Adverse effects include the increased cost contributed by the recommended treatability study and toxicity testing and the possibly low reliability of the method.

### 5.6.6 Discharge Option 1 - Reinjection

**Advantages** - Advantages are:

- Aiding of the recovery system in capturing the plume, and
- Effective disposal of treated water; and
- Maintenance of the groundwater resources.

**Disadvantages** - Disadvantages include:

- Necessary sampling and testing for TCE of injected water;
- Some O&M for wells; and
- Obtaining approval of the TWC.

### 5.6.7 Discharge Option 2 - Discharge to POTW

**Advantages** - Advantages are:

- Effective disposal of treated water; and
- Potential additional treatment at the POTW.

**Disadvantages** - Disadvantages of this discharge option are:

- Relatively high cost;
- Approval of the City of Houston, Public Works Department;
- The need to show that TCE will not pass through the POTW; and
- The need to sample and test for TCE prior to discharge from the site.

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**Appendix A**

**Plume Extent with Time Calculations**

001400

A variety of dispersivities were explored to predict approximate plume lengths with time at the ITS site. The equation chosen

$$C/C_o = \frac{1}{2}\,\mathrm{erfc}\left(\frac{L-\bar{v}t}{2\sqrt{Dt}}\right)$$

assumes that the aquifer is homogeneous, isotropic, and infinite in areal extent and that the source is continuous.

An average velocity for the upper aquifer was calculated from information provided in the RI1 (Table 5-2):

HYDRAULIC CONDUCTIVITY:

| WELL | VALUE |
|---|---|
| MW1 | 0.632 ft/day |
| MW2 | 2.03 |
| MW4 | 0.878 |
| MW5 | 0.221 |
| MW6 | 1.64 |
| MW7 | 1.45 |
| AV. | = 1.24 ft/day |

HYDRAULIC GRADIENT:
RI1 (Table 5-1)

| DATE | GRADIENT |
|---|---|
| 2/16/87 | 0.0036 ft/ft |
| 3/3/87 | 0.0035 |
| 3/22/87 | 0.0030 |
| 7/13/87 | 0.0035 |
| | AV. = 0.0034 |

$$V = -K\frac{dh}{dl} = -0.0034\,(1.24) = 0.004 \text{ ft/day} = 1.5 \text{ ft/yr.}$$

$$\bar{V} = \frac{V}{n} = \text{av. linear velocity} = \frac{0.00422 \frac{ft}{day}}{0.30} = 0.014\frac{ft}{day} = 5.1\frac{ft}{yr.}$$

assumed for unconsolidated sands

The dispersivity ranges for alluvial sediments were obtained from:


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| Method of Measurement | $D_L$ |
|---|---|
| Single Well Test | 0.09 to 18 ft. |
| Two Well Test | 0.27 to 45 ft. |
| Areal Model | 36 to 180 ft. |
| Local Scale | 6.3 to 12 ft. |
| Global Scale | 12 to 60 |
| | 60 to 297 |
| Regional Scale | >300 ft. |

**RADIAN CORPORATION**

# CALCULATION SHEET

CALC. NO.

SIGNATURE K Miller DATE CHECKED MRC DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Plume extent w/ Time SHEET 2 OF 6 SHEETS

Try a variety of dispersivities to find closest match to site conditions.

$$C/C_0 = \frac{5\ ppb}{790\ ppm} = \frac{1}{2}\ \mathrm{erfc}\left(\frac{L-\bar{v}t}{2\sqrt{Dt}}\right)$$

(1) Assume $D = 100$ ft.
$\bar{v} = 5.1$ ft/yr
Find L for various t's

$$\frac{1}{79000} = \mathrm{erfc}\left(\frac{L-5.1t}{20\sqrt{t}}\right)$$

| For t = | L = |
|---|---|
| 1 yr | 66 ft |
| 2 | 96 |
| 5 | 162 |
| 10 | 244 |
| 15 | 313 |
| 20 | 375 |
| 25 | 432 |
| 30 | 487 |
| 100 | 1120 |
| 200 | 1882 |

(2) Assume $D = 200$ ft
$\bar{v} = 5.1$ ft/yr

$$\frac{1}{79000} = \mathrm{erfc}\left(\frac{L-5.1t}{2\sqrt{200t}}\right)$$

| For t = | L = |
|---|---|
| 1 yr | 91 ft |
| 2 | 132 |
| 5 | 218 |
| 10 | 324 |
| 15 | 411 |
| 20 | 488 |
| 25 | 559 |
| 30 | 625 |
| 100 | 1372 |
| 200 | 2240 |

001403

4-81-3361

**RADIAN CORPORATION**

# CALCULATION SHEET

CALC. NO. ____

SIGNATURE MRC DATE ____ CHECKED KMM DATE 5/18/88

PROJECT ITS-FS2 JOB NO. 278-007-39

SUBJECT ____ SHEET 3 OF 6 SHEETS

(3) Assume $D = 10$ ft

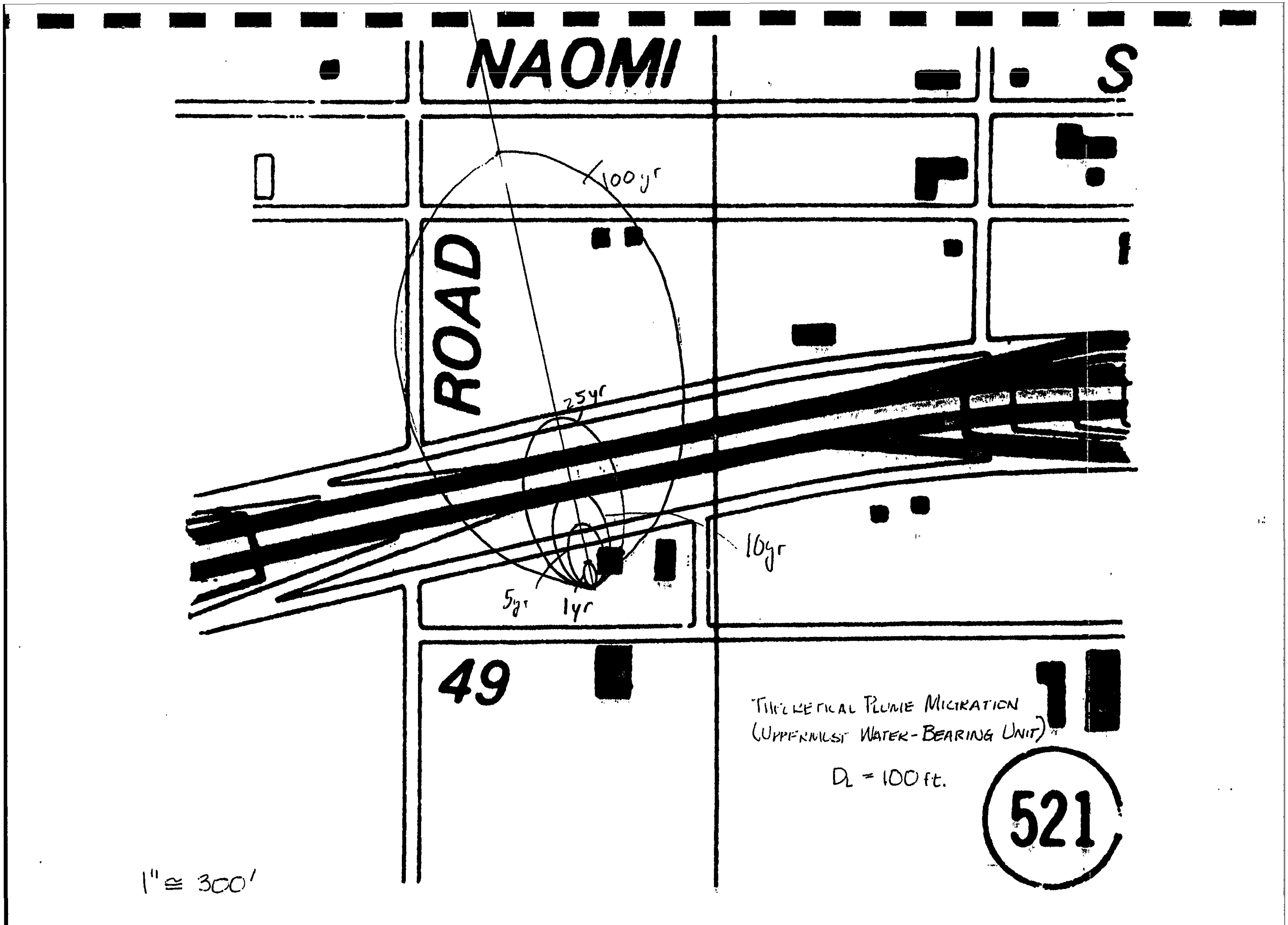
$\bar{v} = 5.1$ ft/day

$$\frac{1}{71000} = \operatorname{erfc}\left(\frac{L - 5.1t}{2\sqrt{10t}}\right)$$

| For t = | L = |
|---|---|
| 1 yr | 24 ft |
| 2 | 37 |
| 5 | 69 |
| 10 | 112 |
| 15 | 151 |
| 20 | 188 |
| 25 | 224 |
| 30 | 259 |
| 50 | 391 |
| 100 | 703 |
| 200 | 1293 |

001404

4-81-3361


NAOMI
S
ROAD
49
521
100yr
25yr
10yr
5yr
1yr
Theoretical Plume Migration
(Uppermost Water-Bearing Unit)
DL = 100 ft.
1" ≅ 300'

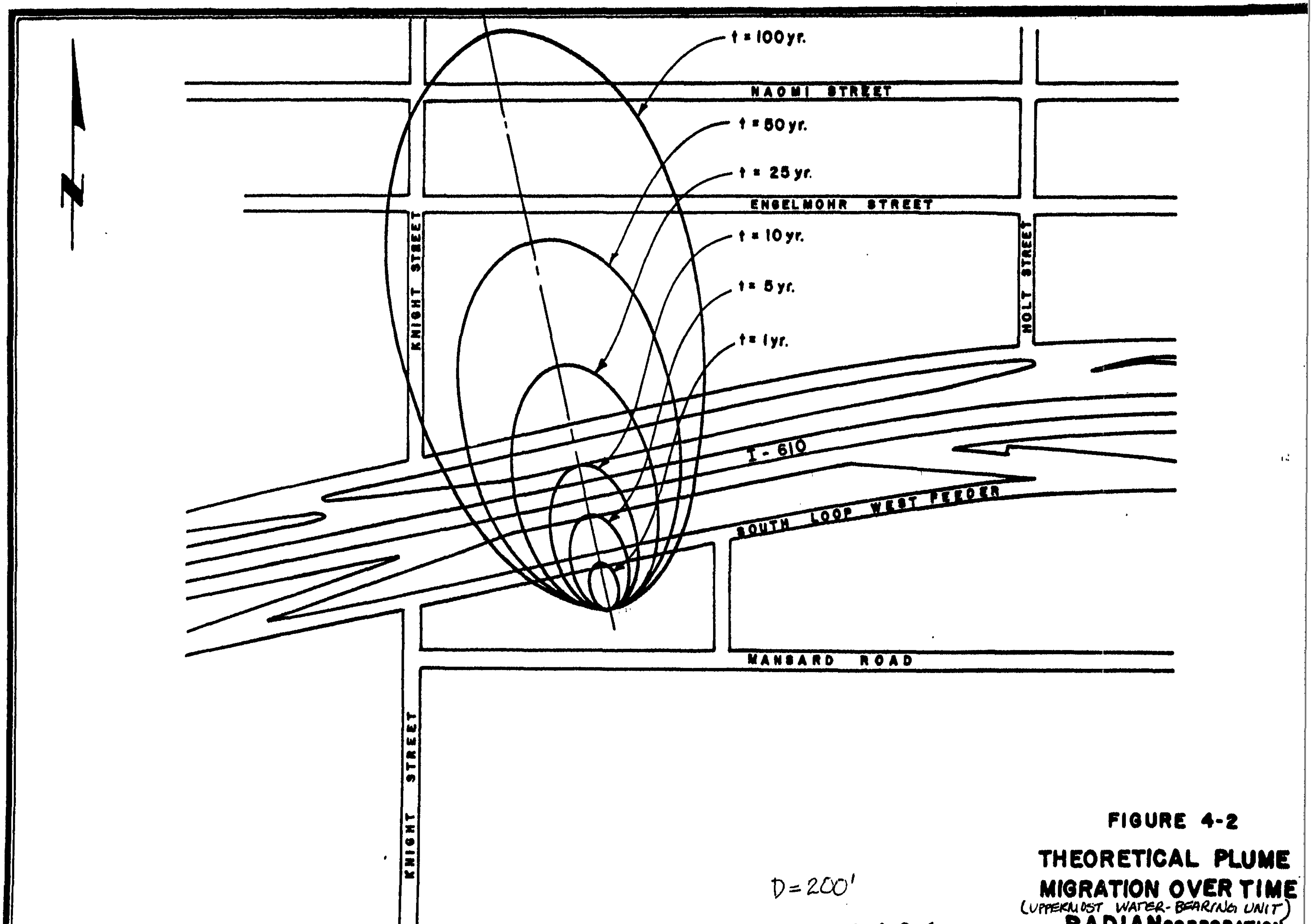



FIGURE 4-2

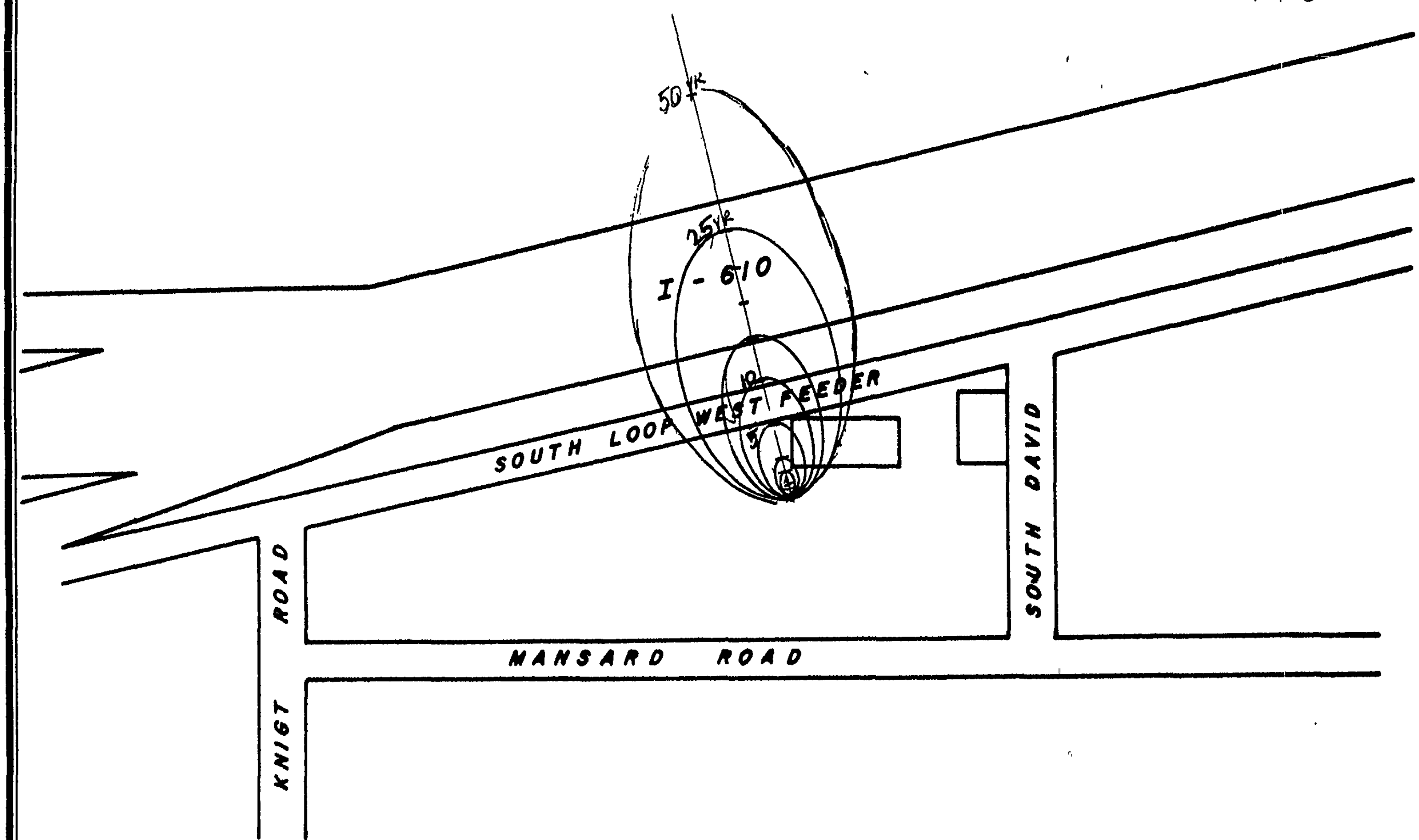
THEORETICAL PLUME MIGRATION OVER TIME

(UPPERMOST WATER-BEARING UNIT)

RADIAN CORPORATION

001406

001406




THEORETICAL PLUME MIGRATION
UPPERMOST WATER-BEARING UNIT

DISPERSIVITY = 10'

1" ≅ 150 ft.

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**Appendix B**

**Drawdown Calculations**

001408

**RADIAN CORPORATION**

# CALCULATION SHEET

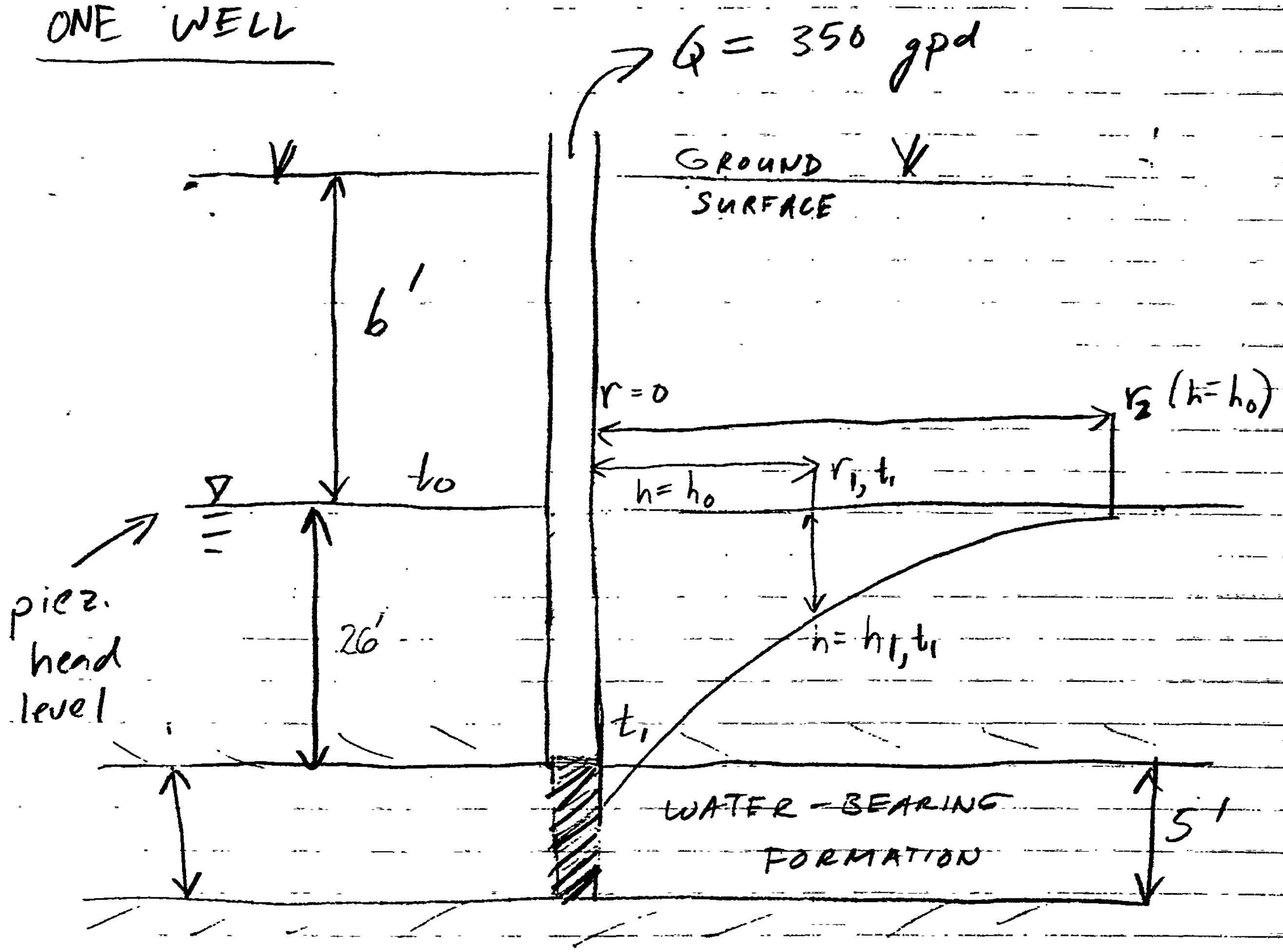
CALC. NO. ______

SIGNATURE Mark Colonna DATE 4/27 CHECKED PJR DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs for Conceptual Recovery System - Uppermost Water-Bearing Unit SHEET 1 OF 11 SHEETS

ONE WELL




$V = 5.1$ ft/yr

$Q = 350$ gpd $= 4.05 \times 10^{-3}$ g/s
(per well)

$T = Kb = (1.24)(5) = 6.2$ ft²/day

$S = (0.? - 0.30)$ F&C $(0.15 - 0.20)$ Soil Survey $=$ use $.175$

Assume confined; thickness 5 ft

$n = 0.30$ ; $h_0 = 31$ ft

Assume isotropic system $K_z = K_r$

$t = 10$ yr $= 3650$ d

001409

4-81-3361

**RADIAN CORPORATION** — **CALCULATION SHEET**

CALC. NO. ______

SIGNATURE: Mark Colonna  DATE: 4/26  CHECKED: RJR  DATE: 5/18/88

PROJECT: ITS - FS2  JOB NO.: 278-007-39

SUBJECT: Drawdown - F+Cherry, Uppermost Water-Bearing Unit  SHEET: 2 OF: 11 SHEETS

(8-5) $$h_0 - h(r,t) = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}\,du}{u} = \frac{Q}{4\pi T} W(u)$$

(8-6) $$u = \frac{r^2 S}{4Tt}$$

$$\frac{S}{4Tt} = \frac{0.175}{(4)(6.2\ ft^2/d)(3650d)} = 1.9333\times10^{-6}/ft^2$$

$r = 20$ ft

$$u = (20\ ft)^2 (1.9333\times10^{-6})/ft^2 = 7.7332\times10^{-4}$$

use $7.7\times10^{-4}$

$W(u) = 6.592$

from table 8-1 - linear interpolation

(F. Mech.)

$$\frac{Q}{4\pi T} = \frac{(350\ gpd)(0.1337\ ft^3/gal)}{(4)(3.1416)(6.2\ ft^2/d)} = 0.6006\ ft$$

$$h_{(20,\ 10yr)} = 31\ ft - (0.6006\ ft)(6.592)$$
$$= 27.04\ ft$$

$\Delta h = 3.96$ ft (drawdown)

001410

4-81-3361

**RADIAN CORPORATION** CALCULATION SHEET

CALC. NO. ____

SIGNATURE Mark Colonna DATE 4/27 CHECKED PJR DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs - Uppermost Water-Bearing Unit SHEET 3 OF ____ SHEETS

r = 50 ft

$u = (50\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 4.8 \times 10^{-3}$

$W(u) = 4.767$

$h_{(50, 10yr)} = 31\ ft - (0.6006 ft)(5.006) = \underline{28.14\ ft}$

$\Delta h = 2.86\ ft$

r = 100 ft

$u = (100 ft)^2 (1.9333 \times 10^{-6})/ft^2 = 1.9 \times 10^{-2}$

$w(u) = 3.419$

$h_{(100, 10yr)} = 31 - (0.6006\ ft)(3.419) = \underline{28.95\ ft}$

$\Delta h = 2.05\ ft$

r = 200 ft

$u = (200\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 7.7 \times 10^{-2}$

$W(u) = 2.066$

$h_{(200, 10yr)} = 31 - (0.6006\ ft)(2.066) = \underline{29.76\ ft}$

$\Delta h = 1.24\ ft$

001411

4-81-3361

**RADIAN CORPORATION**

# CALCULATION SHEET

CALC. NO. ____

SIGNATURE Mark Colonna DATE 4/27/88 CHECKED PJR DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs for Conceptual Recovery System Uppermost Water-Bearing Unit SHEET 4 OF 11 SHEETS

r = 500 ft

$u = (500\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 4.8 \times 10^{-1}$

$W(u) = 0.588$

$h(500, 10_{yr}) = 31 ft - (0.6006\ ft)(0.588) = \underline{30.65\ ft}$

$\Delta h = 0.35\ ft$

r = 10 ft

$u = (10 ft)^2 (1.9333 \times 10^{-6})/ft^2 = 1.9 \times 10^{-4}$

$W(u) = 8.009$

$h(10, 10_{yr}) = 31\ ft - (0.6006)(8.009) = \underline{26.19\ ft}$

$\Delta h = 4.81\ ft$

r = 5 ft

$u = (5\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 4.8 \times 10^{-5}$

$W(u) = 9.374$

$h(5, 10_{yr}) = 31 ft - (0.6006 ft)(9.374) = \underline{25.37 ft}$

$\Delta h = 5.63\ ft$

001412

4-81-3361

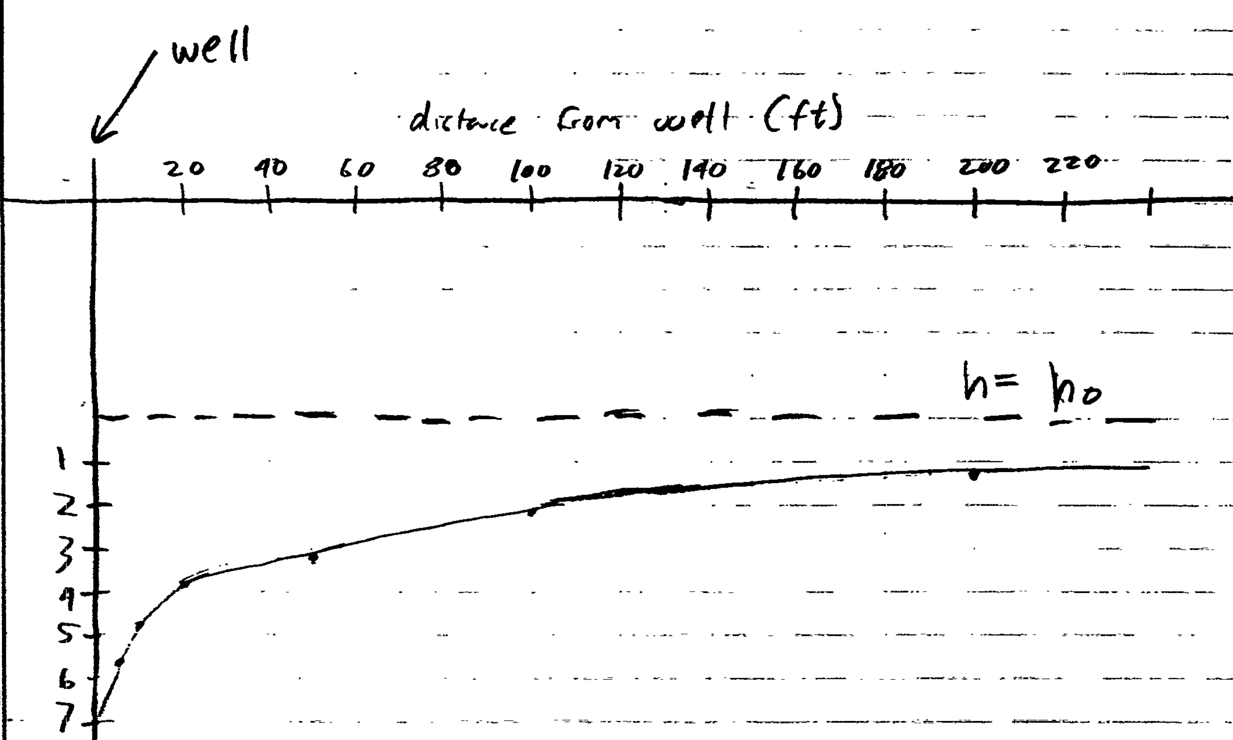
**RADIAN CORPORATION** CALCULATION SHEET

CALC. NO. ____

SIGNATURE Mark Colonna DATE 4/27 CHECKED PGR DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs Uppermost Water-Bearing Unit SHEET 5 OF 11 SHEETS




001413

4-81-3361

RADIAN CORPORATION

# CALCULATION SHEET

CALC. NO.

SIGNATURE Mark Colonna DATE CHECKED PJR DATE 5/18/88

PROJECT ITS- FS2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs SHEET 6 OF 11 SHEETS

Uppermost Water-Bearing Unit

$r = 1$ ft

$u = 1.9333 \times 10^{-6} \approx 1.9 \times 10^{-6}$

$w(u) = 12.619$

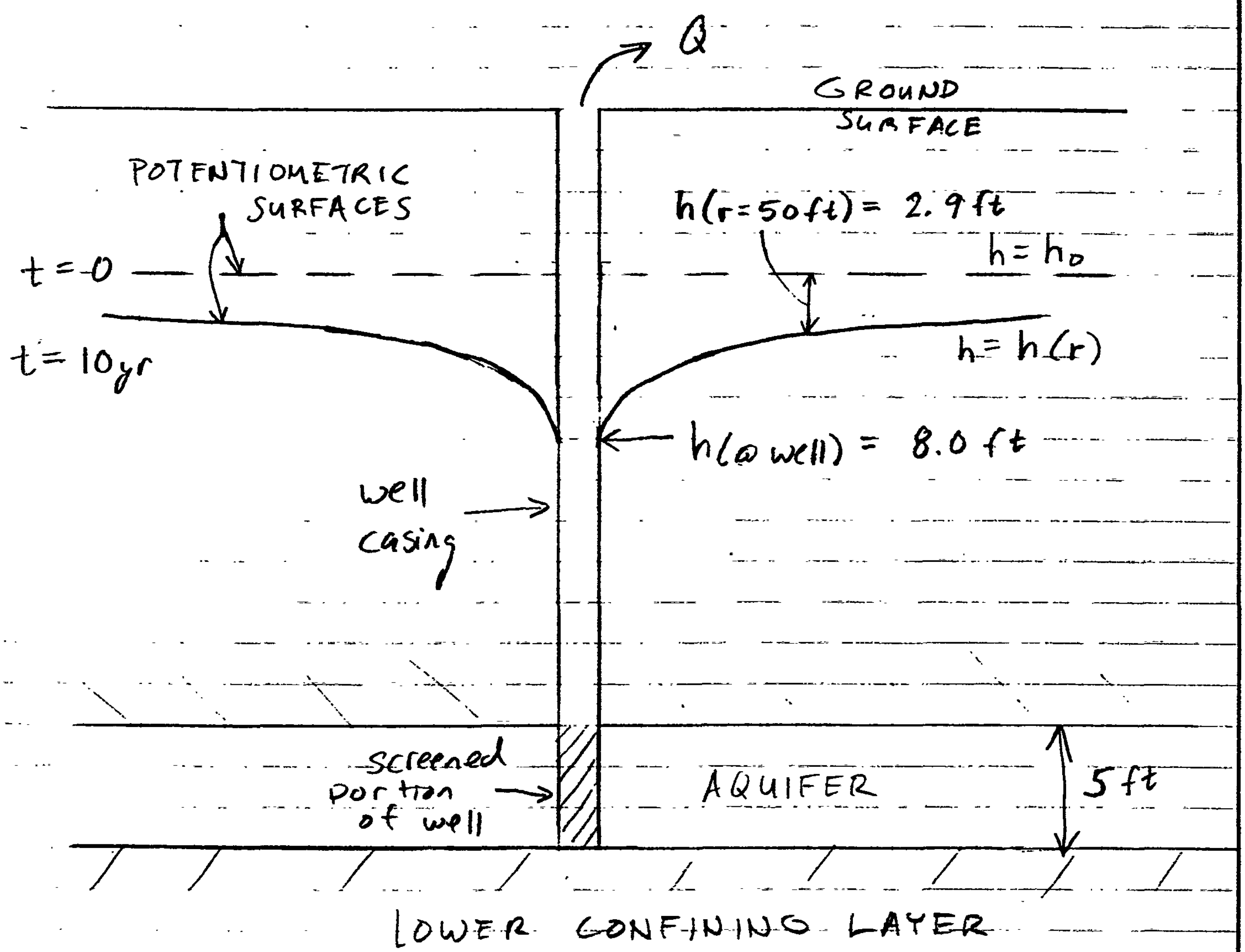
$h(1, 10yr) = 31\text{ft} - (0.6006\text{ ft})(12.619) = \underline{23.42 \text{ f}}$

$\Delta h = 7.58$ ft

001414

4-81-3361

001415




TYPICAL DRAWDOWN FOR ONE RECOVERY WELL

NOT TO SCALE

RADIAN

**RADIAN CORPORATION**

**CALCULATION SHEET**

CALC. NO. ______

SIGNATURE Mark Colonna DATE 4/27 CHECKED PJR DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs Uppermost Water-Bearing Unit SHEET 8 OF 11 SHEETS

$r = 25\ ft$

$u = (25\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 1.2 \times 10^{-3}$

$W(u) = 6.192$

$h_{(25)} = 31 - (0.6006)(6.192) = \underline{27.28\ ft}$

$\Delta h = 3.72\ ft$

$r = 75\ ft$

$u = (75\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 1.1 \times 10^{-2}$

$W(u) = 3.971$

$h_{(75)} = 31 - (0.6006)(3.971) = \underline{28.62\ ft}$

$\Delta h = 2.38\ ft$

$r = 125\ ft$

$u = (125\ ft)^2 (1.9333 \times 10^{-6})/ft^2 = 3.0 \times 10^{-2}$

$W(u) = 2.96$

$h_{(125)} = 31 - (0.6006)(2.96) = \underline{29.22}\ ft$

$\Delta h = 1.78\ ft$

001416

4-81-3361

**RADIAN CORPORATION**

## CALCULATION SHEET

CALC. NO. ______

SIGNATURE Mark Colonna DATE 4/27 CHECKED PJR DATE 5/18/88

PROJECT ITS FS-2 JOB NO. 278-007-39

SUBJECT Drawdown Calcs. Uppermost Water-Bearing Unit SHEET 9 OF 11 SHEETS

$r = 150$ ft

$u = (150 ft)^2 (1.9333 \times 10^{-6}) / ft^2 = 4.3 \times 10^{-2}$

$W(u) = 2.596$

$h_{(150)} = 31$ ft $- (0.6006$ ft$)(2.617) = 29.44$ ft

$\Delta h = 1.56$

$r = 175$ ft

$u = (175 ft)^2 (1.9333 \times 10^{-6}) / ft^2 = 5.9 \times 10^{-2}$

$W(u) = 2.317$

$h_{(175)} = 31$ ft $- (0.6006$ ft$)(2.317) = 29.61$ ft

$\Delta h = 1.39$ ft

Each well (rounded to 1/4')

| | |
|---|---|
| 0 - 8.0 ft | 125 - 1.75 ft |
| 25 - 3.75 ft | 150 - 1.5 ft |
| 50 - 2.75 ft | 175 - 1.5 ft |
| 75 - 2.5 ft | 200 - 1.25 ft |
| 100 - 2.0 ft | |

001417

4-81-3361

**RADIAN CORPORATION** CALCULATION SHEET

CALC. NO. ______

SIGNATURE Mark Colonna DATE 4/27 CHECKED PDR DATE 5/18/88

PROJECT ITS - FS 2 JOB NO. 278-007-39

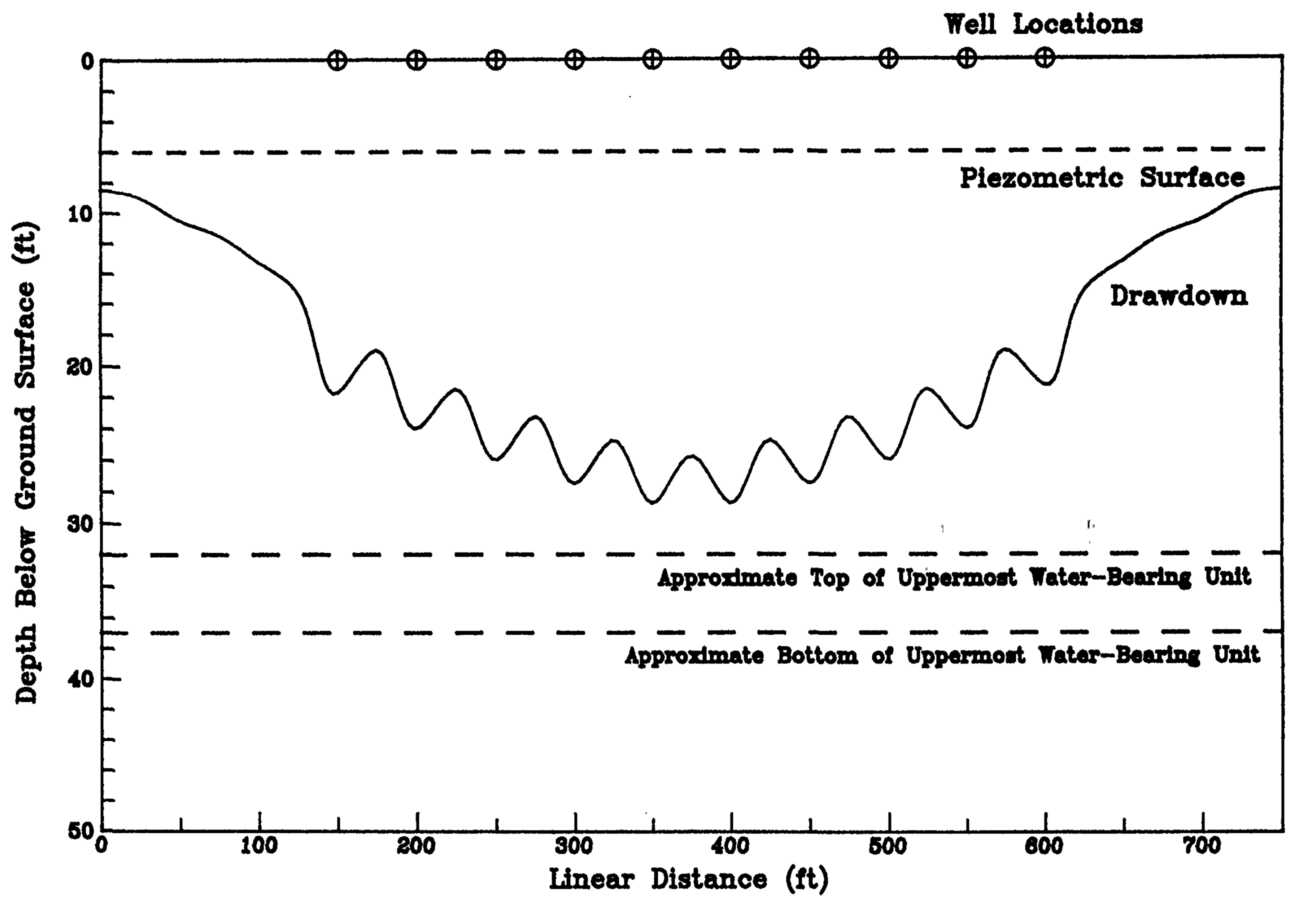
SUBJECT Drawdown from 10 wells Uppermost Water-Bearing Unit SHEET 10 OF 11 SHEETS

Theoretical Cumulative drawdown from 10 wells placed 50 ft apart in the interval x = 150 ft to x = 600 ft

| Distance (linear) | Drawdown (ft) |
|---|---|
| 0 | 2.75 |
| 25 | 3.25 |
| 50 | 4.75 |
| 75 | 5.75 |
| 100 | 7.50 |
| 125 | 9.50 |
| 150 | 15.50 |
| 175 | 13.25 |
| 200 | 18.25 |
| 225 | 15.75 |
| 250 | 20.25 |
| 275 | 17.50 |
| 300 | 21.75 |
| 325 | 19.00 |
| 350 | 23.00 |
| 375 | 19.00 |
| 400 | 23.00 |
| 425 | 19.00 |
| 450 | 21.75 |
| 475 | 17.50 |
| 500 | 20.25 |
| 525 | 15.75 |
| 550 | 18.25 |
| 575 | 13.25 |
| 600 | 15.50 |
| 625 | 9.50 |
| 650 | 7.50 |
| 675 | 5.75 |
| 700 | 4.75 |
| 725 | 3.25 |
| 750 | 2.75 |

001418

4-81-3361




RADIAN CORPORATION



001419

**Appendix C**

**Cost Estimates**

001420

NO ACTION

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 10 YR | $327,481.63 |
| | | TOTAL PW | $364,015 |

001421

DEEP WELL INJECTION

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(30000 GALLON) | | 1 | $12,000 | $12,000.00 |
| CONTAINMENT | | 1 | $8,000 | $8,000.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $77,150.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $7,715.00 |
| ENG/DES | % OF DC | | 7.5% | $5,786.25 |
| ADMIN/INSPEC | % OF DC | | 4% | $3,086.00 |
| | | | TOTAL IDC | $16,587.25 |
| | | | TOTAL CAP | $93,737.25 |
| ANNUAL O&M | | | | |
| TRANSPORT | | 256 | $600 | $153,600.00 |
| FEE | | 11100000 | $0.03 | $333,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $532,137.50 |
| | | | O&M 10 YR | $4,316,167.26 |
| | | | TOTAL PW | $4,409,905 |

001422

CARBON ADSORPTION

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| COLUMN SYSTEM | | 1 | $45,000 | $45,000.00 |
| BUILDING TO HOUSE COLUMNS | | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $14,350.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $143,500.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $14,350.00 |
| ENG/DES | % OF DC | | 10% | $14,350.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,740.00 |
| | | | TOTAL IDC | $34,440.00 |
| | | | TOTAL CAP | $177,940.00 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 24000 | $2 | $48,000.00 |
| CARBON SAMP | | 52 | $300 | $15,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $109,137.50 |
| | | | O&M 10 YR | $885,214.26 |
| | | | TOTAL PW | $1,063,154 |

001423

AIR STRIPPING

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| STRIPPER | | 1 | $10,000 | $10,000.00 |
| CARBON COL | | 1 | $25,000 | $25,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $12,794.44 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $127,944.44 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $12,794.44 |
| ENG/DES | % OF DC | | 10% | $12,794.44 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,117.78 |
| | | | TOTAL IDC | $30,706.67 |
| | | | TOTAL CAP | $158,651.11 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 6000 | $2 | $12,000.00 |
| CARBON SAMP | | 12 | $300 | $3,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $61,137.50 |
| | | | O&M 10 YR | $495,886.26 |
| | | | TOTAL PW | $654,537 |

001424

CATALYTIC DEHYDROCHLORINATION

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 10 | $1,440 | $14,400.00 |
| PIPING | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | 1 | $10,000 | $10,000.00 |
| LAB STUDY | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | 1 | $225,000 | $225,000.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 16 | $75 | $1,200.00 |
| | | TOTAL DC | $327,650.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $32,765.00 |
| ENG/DES | % OF DC | 10% | $32,765.00 |
| ADMIN/INSPEC | % OF DC | 4% | $13,106.00 |
| | | TOTAL IDC | $78,636.00 |
| | | TOTAL CAP | $406,286.00 |
| ANNUAL O&M | | | |
| REAGENT | 5600 | $20 | $112,000.00 |
| WASTE DISPOSAL | 5600 | $20 | $112,000.00 |
| FIELD LABOR | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | 1 | $75,000 | $75,000.00 |
| MAINT | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | $674,537.50 |
| | | O&M 10 YR | $5,471,173.66 |
| | | TOTAL PW | $5,877,460 |

001425

REINJECTION ON-SITE

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| INJECTION WELLS | 10 | $1,440 | $14,400.00 |
| PIPING | 1 | $4,300 | $4,300.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| | | TOTAL DC | $19,750.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | 1975 |
| ENG/DES | % OF DC | 10% | 1975 |
| ADMIN/INSPEC | % OF DC | 4% | 790 |
| PERMITTING | % OF DC | 0.5% | 98.75 |
| | | TOTAL IDC | 4838.75 |
| | | TOTAL CAP | $24,588.75 |
| ANNUAL O&M | | | |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | $5,162.50 |
| | | O&M 10 YR | $41,873.04 |
| | | TOTAL PW | $66,462 |

001426

DISCHARGE TO POTW

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
| --- | --- | --- | --- |
| DIRECT COSTS | | | |
| CAPACITY FEE | 1 | $2,776 | $2,776.00 |
| PIPING | 1 | 1000 | $1,000.00 |
| | | TOTAL DC | $3,776.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $377.60 |
| ENG/DES | % OF DC | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | 4% | $151.04 |
| PERMITTING | % OF DC | 0.5% | $18.88 |
| | | TOTAL IDC | 925.12 |
| | | TOTAL CAP | $4,701.12 |
| ANNUAL O&M | | | |
| USER CHARGE | 1277500 | $0.02 | $25,550.00 |
| | | TOT AN O&M | $25,550.00 |
| | | O&M 10 YR | $207,236.05 |
| | | TOTAL PW | $211,937 |

001427

Appendix D

Cost Sensitivity Calculations

001428

NO ACTION (2X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO B"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 10 YR | $327,481.63 |
| | | TOTAL PW | $364,015 |

001429

DEEP WELL INJECTION (2X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO B"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 20 | $1,440 | $28,800.00 |
| PIPING | 2 | $4,300 | $8,600.00 |
| TANK (30000 GALLON) | 1 | $12,000 | $12,000.00 |
| CONTAINMENT | 1 | $8,000 | $8,000.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 2 | $1,000 | $2,000.00 |
| EQUIP & LABOR | 24 | $75 | $1,800.00 |
| | | TOTAL DC | $97,450.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $9,745.00 |
| ENG/DES | % OF DC | 7.5% | $7,308.75 |
| ADMIN/INSPEC | % OF DC | 4% | $3,898.00 |
| | | TOTAL IDC | $20,951.75 |
| | | TOTAL CAP | $118,401.75 |
| ANNUAL O&M | | | |
| TRANSPORT | 256 | $600 | $153,600.00 |
| FEE | 11100000 | $0.03 | $333,000.00 |
| WATER SAMP (4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP (5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 192 | $25 | $4,800.00 |
| | | TOT AN O&M | $534,537.50 |
| | | O&M 10 YR | $4,335,633.66 |
| | | TOTAL PW | $4,454,035 |

001430

CARBON ADSORPTION (2X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO B"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 20 | $1,440 | $28,800.00 |
| PIPING | | 2 | $4,300 | $8,600.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| COLUMN SYSTEM | | 1 | $45,000 | $45,000.00 |
| BUILDING TO HOUSE COLUMNS | | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $16,605.56 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 2 | $1,000 | $2,000.00 |
| EQUIP & LABOR | | 24 | $75 | $1,800.00 |
| | | | TOTAL DC | $166,055.56 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $16,605.56 |
| ENG/DES | % OF DC | | 10% | $16,605.56 |
| ADMIN/INSPEC | % OF DC | | 4% | $6,642.22 |
| | | | TOTAL IDC | $39,853.33 |
| | | | TOTAL CAP | $205,908.89 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 24000 | $2 | $48,000.00 |
| CARBON SAMP | | 52 | $300 | $15,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 192 | $25 | $4,800.00 |
| | | | TOT AN O&M | $111,537.50 |
| | | | O&M 10 YR | $904,680.66 |
| | | | TOTAL PW | $1,110,590 |

001431

AIR STRIPPING (2X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO B"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 20 | $1,440 | $28,800.00 |
| PIPING | | 2 | $4,300 | $8,600.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| STRIPPER | | 1 | $10,000 | $10,000.00 |
| CARBON COL | | 1 | $25,000 | $25,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $15,051.86 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 2 | $1,000 | $2,000.00 |
| EQUIP & LABOR | | 24 | $75 | $1,800.00 |
| | | | TOTAL DC | $150,501.86 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $15,050.19 |
| ENG/DES | % OF DC | | 10% | $15,050.19 |
| ADMIN/INSPEC | % OF DC | | 4% | $6,020.07 |
| | | | TOTAL IDC | $36,120.45 |
| | | | TOTAL CAP | $186,622.30 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 6000 | $2 | $12,000.00 |
| CARBON SAMP | | 12 | $300 | $3,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 192 | $25 | $4,800.00 |
| | | | TOT AN O&M | $63,537.50 |
| | | | O&M 10 YR | $515,352.66 |
| | | | TOTAL PW | $701,975 |

001432

CATALYTIC DEHYDROCHLORINATION (2X WELLS-SAME TOTAL PUMPING RATE "SCENARIO B"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 20 | $1,440 | $28,800.00 |
| PIPING | 2 | $4,300 | $8,600.00 |
| TANK(10000 GALLON) | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | 1 | $10,000 | $10,000.00 |
| LAB STUDY | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | 1 | $225,000 | $225,000.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 2 | $1,000 | $2,000.00 |
| EQUIP & LABOR | 24 | $75 | $1,800.00 |
| | | TOTAL DC | $347,950.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $34,795.00 |
| ENG/DES | % OF DC | 10% | $34,795.00 |
| ADMIN/INSPEC | % OF DC | 4% | $13,918.00 |
| | | TOTAL IDC | $83,508.00 |
| | | TOTAL CAP | $431,458.00 |
| ANNUAL O&M | | | |
| REAGENT | 5600 | $20 | $112,000.00 |
| WASTE DISPOSAL | 5600 | $20 | $112,000.00 |
| FIELD LABOR | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | 1 | $75,000 | $75,000.00 |
| MAINT | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 192 | $25 | $4,800.00 |
| | | TOT AN O&M | $676,937.50 |
| | | O&M 10 YR | $5,490,640.06 |
| | | TOTAL PW | $5,922,098 |

001433

REINJECTION ON-SITE (2X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO B"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| INJECTION WELLS | 20 | $1,440 | $28,800.00 |
| PIPING | 2 | $4,300 | $8,600.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| | | TOTAL DC | $38,450.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | 3845 |
| ENG/DES | % OF DC | 10% | 3845 |
| ADMIN/INSPEC | % OF DC | 4% | 1538 |
| PERMITTING | % OF DC | 0.5% | 192.25 |
| | | TOTAL IDC | 9420.25 |
| | | TOTAL CAP | $47,870.25 |
| ANNUAL O&M | | | |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 192 | $25 | $4,800.00 |
| | | TOT AN O&M | $7,562.50 |
| | | O&M 10 YR | $61,339.44 |
| | | TOTAL PW | $109,210 |

001434

DISCHARGE TO POTW (2X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO B"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| CAPACITY FEE | 1 | $2,776 | $2,776.00 |
| PIPING | 1 | 1000 | $1,000.00 |
| | | TOTAL DC | $3,776.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $377.60 |
| ENG/DES | % OF DC | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | 4% | $151.04 |
| PERMITTING | % OF DC | 0.5% | $18.88 |
| | | TOTAL IDC | 925.12 |
| | | TOTAL CAP | $4,701.12 |
| ANNUAL O&M | | | |
| USER CHARGE | 1277500 | $0.02 | $25,550.00 |
| | | TOT AN O&M | $25,550.00 |
| | | O&M 10 YR | $207,236.05 |
| | | TOTAL PW | $211.937 |

001435

NO ACTION (5X WELLS-350 GPD PER WELL) "SCENARIO C"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 10 YR | $327,481.63 |
| | | TOTAL PW | $364,015 |

001436

DEEP WELL INJECTION (5X WELLS-350 GPD PER WELL) "SCENARIO C"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| TANK(30000 GALLON) | | 5 | $12,000 | $60,000.00 |
| CONTAINMENT | | 2 | $8,000 | $16,000.00 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | | 40 | $75 | $3,000.00 |
| | | | TOTAL DC | $214,800.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $21,480.00 |
| ENG/DES | % OF DC | | 7.5% | $16,110.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $8,592.00 |
| | | | TOTAL IDC | $46,182.00 |
| | | | TOTAL CAP | $260,982.00 |
| ANNUAL O&M | | | | |
| TRANSPORT | | 1280 | $600 | $768,000.00 |
| FEE | | 55500000 | $0.03 | $1,665,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $2,490,900.00 |
| | | | O&M 10 YR | $20,203,689.90 |
| | | | TOTAL PW | $20,464,672 |

001437

CARBON ADSORPTION (5X WELLS-350 GPD PER WELL) "SCENARIO C"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 50 | $1,440 | $72,000.00 |
| PIPING | 5 | $4,300 | $21,500.00 |
| TANK(10000 GALLON) | 10 | $6,500 | $65,000.00 |
| CONTAINMENT | 2 | $10,000 | $20,000.00 |
| COLUMN SYSTEM | 2 | $45,000 | $90,000.00 |
| BUILDING TO HOUSE COLUMNS | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | 10% | $35,311.11 |
| GENERATOR | 2 | $1,050 | $2,100.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | 40 | $75 | $3,000.00 |
| | | TOTAL DC | $353,111.11 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $35,311.11 |
| ENG/DES | % OF DC | 10% | $35,311.11 |
| ADMIN/INSPEC | % OF DC | 4% | $14,124.44 |
| | | TOTAL IDC | $84,746.67 |
| | | TOTAL CAP | $437,857.78 |
| ANNUAL O&M | | | |
| CARBON REGEN | 120000 | $2 | $240,000.00 |
| CARBON SAMP | 104 | $300 | $31,200.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | 480 | $25 | $12,000.00 |
| | | TOT AN O&M | $329,100.00 |
| | | O&M 10 YR | $2,669,330.10 |
| | | TOTAL PW | $3,107,188 |

AIR STRIPPING (5X WELLS-350 GPD PER WELL) "SCENARIO C"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| TANK(10000 GALLON) | | 10 | $6,500 | $65,000.00 |
| CONTAINMENT | | 2 | $10,000 | $20,000.00 |
| STRIPPER | | 2 | $10,000 | $20,000.00 |
| CARBON COL | | 2 | $25,000 | $50,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $32,644.44 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | | 40 | $75 | $3,000.00 |
| | | | TOTAL DC | $326,444.44 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $32,644.44 |
| ENG/DES | % OF DC | | 10% | $32,644.44 |
| ADMIN/INSPEC | % OF DC | | 4% | $13,057.78 |
| | | | TOTAL IDC | $78,346.67 |
| | | | TOTAL CAP | $404,791.11 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 30000 | $2 | $60,000.00 |
| CARBON SAMP | | 24 | $300 | $7,200.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $125,100.00 |
| | | | O&M 10 YR | $1,014,686.10 |
| | | | TOTAL PW | $1,419,477 |

001439

CATALYTIC DEHYDROCHLORINATION (5X WELLS-350 GPD PER DAY PER WEL "SCENARIO C"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| TANK(10000 GALLON) | | 10 | $6,500 | $65,000.00 |
| CONTAINMENT | | 2 | $10,000 | $20,000.00 |
| LAB STUDY | | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | | 1 | $225,000 | $225,000.00 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | | 40 | $75 | $3,000.00 |
| | | | TOTAL DC | $471,300.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $47,130.00 |
| ENG/DES | % OF DC | | 10% | $47,130.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $18,852.00 |
| | | | TOTAL IDC | $113,112.00 |
| | | | TOTAL CAP | $584,412.00 |
| ANNUAL O&M | | | | |
| REAGENT | | 28000 | $20 | $560,000.00 |
| WASTE DISPOSAL | | 28000 | $20 | $560,000.00 |
| FIELD LABOR | | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | | 1 | $75,000 | $75,000.00 |
| MAINT | | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $1,582,900.00 |
| | | | O&M 10 YR | $12,838,901.90 |
| | | | TOTAL PW | $13,423,314 |

001440

REINJECTION ON-SITE (5X WELLS-350 GPD PER WELL) "SCENARIO C"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| INJECTION WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| | | | TOTAL DC | $95,600.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | 9560 |
| ENG/DES | % OF DC | | 10% | 9560 |
| ADMIN/INSPEC | % OF DC | | 4% | 3824 |
| PERMITTING | % OF DC | | 0.5% | 478 |
| | | | TOTAL IDC | 23422 |
| | | | TOTAL CAP | $119,022.00 |
| ANNUAL O&M | | | | |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $17,525.00 |
| | | | O&M 10 YR | $142,145.28 |
| | | | TOTAL PW | $261,167 |

001441

DISCHARGE TO POTW (5X WELLS-350 GPD PER WELL) "SCENARIO C"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| CAPACITY FEE | 1 | $2,776 | $2,776.00 |
| PIPING | 1 | 1000 | $1,000.00 |
| | | TOTAL DC | $3,776.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $377.60 |
| ENG/DES | % OF DC | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | 4% | $151.04 |
| PERMITTING | % OF DC | 0.5% | $18.88 |
| | | TOTAL IDC | 925.12 |
| | | TOTAL CAP | $4,701.12 |
| ANNUAL O&M | | | |
| USER CHARGE | 6387500 | $0.02 | $127,750.00 |
| | | TOT AN O&M | $127,750.00 |
| | | O&M 10 YR | $1,036,180.25 |
| | | TOTAL PW | $1,040,881 |

001442

NO ACTION (5X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO D"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 10 YR | $327,481.63 |
| | | TOTAL PW | $364,015 |

001443

DEEP WELL INJECTION (5X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO D"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| TANK(30000 GALLON) | | 1 | $12,000 | $12,000.00 |
| CONTAINMENT | | 1 | $8,000 | $8,000.00 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | | 40 | $75 | $3,000.00 |
| | | | TOTAL DC | $158,800.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $15,880.00 |
| ENG/DES | % OF DC | | 7.5% | $11,910.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $6,352.00 |
| | | | TOTAL IDC | $34,142.00 |
| | | | TOTAL CAP | $192,942.00 |
| ANNUAL O&M | | | | |
| TRANSPORT | | 256 | $600 | $153,600.00 |
| FEE | | 11100000 | $0.03 | $333,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $544,500.00 |
| | | | O&M 10 YR | $4,416,439.50 |
| | | | TOTAL PW | $4,609,382 |

001444

CARBON ADSORPTION (5X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO D"

| ACTIVITY | | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| COLUMN SYSTEM | | 1 | $45,000 | $45,000.00 |
| BUILDING TO HOUSE COLUMNS | | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $23,422.22 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | | 40 | $75 | $3,000.00 |
| | | | TOTAL DC | $234,222.22 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $23,422.22 |
| ENG/DES | % OF DC | | 10% | $23,422.22 |
| ADMIN/INSPEC | % OF DC | | 4% | $9,368.89 |
| | | | TOTAL IDC | $56,213.33 |
| | | | TOTAL CAP | $290,435.56 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 24000 | $2 | $48,000.00 |
| CARBON SAMP | | 52 | $300 | $15,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $121,500.00 |
| | | | O&M 10 YR | $985,486.50 |
| | | | TOTAL PW | $1,275,922 |

001445

AIR STRIPPING (5X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO D"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| STRIPPER | | 1 | $10,000 | $10,000.00 |
| CARBON COL | | 1 | $25,000 | $25,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $21,866.67 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | | 40 | $75 | $3,000.00 |
| | | | TOTAL DC | $218,666.67 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $21,866.67 |
| ENG/DES | % OF DC | | 10% | $21,866.67 |
| ADMIN/INSPEC | % OF DC | | 4% | $8,746.67 |
| | | | TOTAL IDC | $52,480.00 |
| | | | TOTAL CAP | $271,146.67 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 6000 | $2 | $12,000.00 |
| CARBON SAMP | | 12 | $300 | $3,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $73,500.00 |
| | | | O&M 10 YR | $596,158.50 |
| | | | TOTAL PW | $867,305 |

001446

CATALYTIC DEHYDROCHLORINATION (5X WELLS-SAME TOTAL PUMPING RATE "SCENARIO D"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 50 | $1,440 | $72,000.00 |
| PIPING | 5 | $4,300 | $21,500.00 |
| TANK(10000 GALLON) | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | 1 | $10,000 | $10,000.00 |
| LAB STUDY | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | 1 | $225,000 | $225,000.00 |
| GENERATOR | 2 | $1,050 | $2,100.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 5 | $1,000 | $5,000.00 |
| EQUIP & LABOR | 40 | $75 | $3,000.00 |
| | | TOTAL DC | $409,300.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $40,930.00 |
| ENG/DES | % OF DC | 10% | $40,930.00 |
| ADMIN/INSPEC | % OF DC | 4% | $16,372.00 |
| | | TOTAL IDC | $98,232.00 |
| | | TOTAL CAP | $507,532.00 |
| ANNUAL O&M | | | |
| REAGENT | 5600 | $20 | $112,000.00 |
| WASTE DISPOSAL | 5600 | $20 | $112,000.00 |
| FIELD LABOR | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | 1 | $75,000 | $75,000.00 |
| MAINT | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | 480 | $25 | $12,000.00 |
| | | TOT AN O&M | $686,900.00 |
| | | O&M 10 YR | $5,571,445.90 |
| | | TOTAL PW | $6,078,978 |

001447

REINJECTION ON-SITE (5X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO D"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| INJECTION WELLS | | 50 | $1,440 | $72,000.00 |
| PIPING | | 5 | $4,300 | $21,500.00 |
| GENERATOR | | 2 | $1,050 | $2,100.00 |
| | | | TOTAL DC | $95,600.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | 9560 |
| ENG/DES | % OF DC | | 10% | 9560 |
| ADMIN/INSPEC | % OF DC | | 4% | 3824 |
| PERMITTING | % OF DC | | 0.5% | 478 |
| | | | TOTAL IDC | 23422 |
| | | | TOTAL CAP | $119,022.00 |
| ANNUAL O&M | | | | |
| GAS | | 6500 | $0.85 | $5,525.00 |
| PUMP/GEN MAINT | | 480 | $25 | $12,000.00 |
| | | | TOT AN O&M | $17,525.00 |
| | | | O&M 10 YR | $142,145.28 |
| | | | TOTAL PW | $261,167 |

001448

DISCHARGE TO POTW (5X WELLS-SAME TOTAL PUMPING RATE) "SCENARIO D"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| CAPACITY FEE | | 1 | $2,776 | $2,776.00 |
| PIPING | | 1 | 1000 | $1,000.00 |
| | | | TOTAL DC | $3,776.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $377.60 |
| ENG/DES | % OF DC | | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | | 4% | $151.04 |
| PERMITTING | % OF DC | | 0.5% | $18.88 |
| | | | TOTAL IDC | 925.12 |
| | | | TOTAL CAP | $4,701.12 |
| ANNUAL O&M | | | | |
| USER CHARGE | | 1277500 | $0.02 | $25,550.00 |
| | | | TOT AN O&M | $25,550.00 |
| | | | O&M 10 YR | $207,236.05 |
| | | | TOTAL PW | $211,937 |

001449

NO ACTION (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 20 YR | $548,696.25 |
| | | TOTAL PW | $585,229 |

001450

DEEP WELL INJECTION (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 10 | $1,440 | $14,400.00 |
| PIPING | 1 | $4,300 | $4,300.00 |
| TANK(30000 GALLON) | 1 | $12,000 | $12,000.00 |
| CONTAINMENT | 1 | $8,000 | $8,000.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 16 | $75 | $1,200.00 |
| | | TOTAL DC | $77,150.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $7,715.00 |
| ENG/DES | % OF DC | 7.5% | $5,786.25 |
| ADMIN/INSPEC | % OF DC | 4% | $3,086.00 |
| | | TOTAL IDC | $16,587.25 |
| | | TOTAL CAP | $93,737.25 |
| ANNUAL O&M | | | |
| TRANSPORT | 256 | $600 | $153,600.00 |
| FEE | 11100000 | $0.03 | $333,000.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | $532,137.50 |
| | | O&M 20 YR | $7,231,748.63 |
| | | TOTAL PW | $7,325,486 |

001451

CARBON ADSORPTION (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| COLUMN SYSTEM | | 1 | $45,000 | $45,000.00 |
| BUILDING TO HOUSE COLUMNS | | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $14,350.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $143,500.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $14,350.00 |
| ENG/DES | % OF DC | | 10% | $14,350.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,740.00 |
| | | | TOTAL IDC | $34,440.00 |
| | | | TOTAL CAP | $177,940.00 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 24000 | $2 | $48,000.00 |
| CARBON SAMP | | 52 | $300 | $15,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $109,137.50 |
| | | | O&M 20 YR | $1,483,178.63 |
| | | | TOTAL PW | $1,661,119 |

001452

AIR STRIPPING (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| STRIPPER | | 1 | $10,000 | $10,000.00 |
| CARBON COL | | 1 | $25,000 | $25,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $12,794.44 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $127,944.44 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $12,794.44 |
| ENG/DES | % OF DC | | 10% | $12,794.44 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,117.78 |
| | | | TOTAL IDC | $30,706.67 |
| | | | TOTAL CAP | $158,651.11 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 6000 | $2 | $12,000.00 |
| CARBON SAMP | | 12 | $300 | $3,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $61,137.50 |
| | | | O&M 20 YR | $830,858.63 |
| | | | TOTAL PW | $989,510 |

001453

CATALYTIC DEHYDROCHLORINATION (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| LAB STUDY | | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | | 1 | $225,000 | $225,000.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $327,650.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $32,765.00 |
| ENG/DES | % OF DC | | 10% | $32,765.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $13,106.00 |
| | | | TOTAL IDC | $78,636.00 |
| | | | TOTAL CAP | $406,286.00 |
| ANNUAL O&M | | | | |
| REAGENT | | 5600 | $20 | $112,000.00 |
| WASTE DISPOSAL | | 5600 | $20 | $112,000.00 |
| FIELD LABOR | | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | | 1 | $75,000 | $75,000.00 |
| MAINT | | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $674,537.50 |
| | | | O&M 20 YR | $9,166,964.63 |
| | | | TOTAL PW | $9,573,251 |

001454

REINJECTION ON-SITE (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| INJECTION WELLS | 10 | $1,440 | $14,400.00 |
| PIPING | 1 | $4,300 | $4,300.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| | | TOTAL DC | $19,750.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | 1975 |
| ENG/DES | % OF DC | 10% | 1975 |
| ADMIN/INSPEC | % OF DC | 4% | 790 |
| PERMITTING | % OF DC | 0.5% | 98.75 |
| | | TOTAL IDC | 4838.75 |
| | | TOTAL CAP | $24,588.75 |
| ANNUAL O&M | | | |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | $5,162.50 |
| | | O&M 20 YR | $70,158.38 |
| | | TOTAL PW | $94,747 |

001455

DISCHARGE TO POTW (2X TIME) "SCENARIO E"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| CAPACITY FEE | 1 | $2,776 | $2,776.00 |
| PIPING | 1 | 1000 | $1,000.00 |
| | | TOTAL DC | $3,776.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $377.60 |
| ENG/DES | % OF DC | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | 4% | $151.04 |
| PERMITTING | % OF DC | 0.5% | $18.88 |
| | | TOTAL IDC | 925.12 |
| | | TOTAL CAP | $4,701.12 |
| ANNUAL O&M | | | |
| USER CHARGE | 1277500 | $0.02 | $25,550.00 |
| | | TOT AN O&M | $25,550.00 |
| | | O&M 20 YR | $347,224.50 |
| | | TOTAL PW | $351,926 |

001456

NO ACTION (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 5 YR | $179,749.50 |
| | | TOTAL PW | $216,283 |

001457

DEEP WELL INJECTION (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 10 | $1,440 | $14,400.00 |
| PIPING | 1 | $4,300 | $4,300.00 |
| TANK(30000 GALLON) | 1 | $12,000 | $12,000.00 |
| CONTAINMENT | 1 | $8,000 | $8,000.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 16 | $75 | $1,200.00 |
| | | TOTAL DC | $77,150.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $7,715.00 |
| ENG/DES | % OF DC | 7.5% | $5,786.25 |
| ADMIN/INSPEC | % OF DC | 4% | $3,086.00 |
| | | TOTAL IDC | $16,587.25 |
| | | TOTAL CAP | $93,737.25 |
| ANNUAL O&M | | | |
| TRANSPORT | 256 | $600 | $153,600.00 |
| FEE | 11100000 | $0.03 | $333,000.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | $532,137.50 |
| | | O&M 5 YR | $2,369,076.15 |
| | | TOTAL PW | $2,462,813 |

001458

CARBON ADSORPTION (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| COLUMN SYSTEM | | 1 | $45,000 | $45,000.00 |
| BUILDING TO HOUSE COLUMNS | | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $14,350.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $143,500.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $14,350.00 |
| ENG/DES | % OF DC | | 10% | $14,350.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,740.00 |
| | | | TOTAL IDC | $34,440.00 |
| | | | TOTAL CAP | $177,940.00 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 24000 | $2 | $48,000.00 |
| CARBON SAMP | | 52 | $300 | $15,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $109,137.50 |
| | | | O&M 5 YR | $485,880.15 |
| | | | TOTAL PW | $663,820 |

001459

AIR STRIPPING (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| STRIPPER | | 1 | $10,000 | $10,000.00 |
| CARBON COL | | 1 | $25,000 | $25,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $12,794.44 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $127,944.44 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $12,794.44 |
| ENG/DES | % OF DC | | 10% | $12,794.44 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,117.78 |
| | | | TOTAL IDC | $30,706.67 |
| | | | TOTAL CAP | $158,651.11 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 6000 | $2 | $12,000.00 |
| CARBON SAMP | | 12 | $300 | $3,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $61,137.50 |
| | | | O&M 5 YR | $272,184.15 |
| | | | TOTAL PW | $430,835 |

001460

CATALYTIC DEHYDROCHLORINATION (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| LAB STUDY | | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | | 1 | $225,000 | $225,000.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $327,650.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $32,765.00 |
| ENG/DES | % OF DC | | 10% | $32,765.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $13,106.00 |
| | | | TOTAL IDC | $78,636.00 |
| | | | TOTAL CAP | $406,286.00 |
| ANNUAL O&M | | | | |
| REAGENT | | 5600 | $20 | $112,000.00 |
| WASTE DISPOSAL | | 5600 | $20 | $112,000.00 |
| FIELD LABOR | | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | | 1 | $75,000 | $75,000.00 |
| MAINT | | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $674,537.50 |
| | | | O&M 5 YR | $3,003,040.95 |
| | | | TOTAL PW | $3,409,327 |

001461

REINJECTION ON-SITE (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| INJECTION WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| | | | TOTAL DC | $19,750.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | 1975 |
| ENG/DES | % OF DC | | 10% | 1975 |
| ADMIN/INSPEC | % OF DC | | 4% | 790 |
| PERMITTING | % OF DC | | 0.5% | 98.75 |
| | | | TOTAL IDC | 4838.75 |
| | | | TOTAL CAP | $24,588.75 |
| ANNUAL O&M | | | | |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $5,162.50 |
| | | | O&M 5 YR | $22,983.45 |
| | | | TOTAL PW | $47,572 |

001462

DISCHARGE TO POTW (1/2 TIME) "SCENARIO F"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| CAPACITY FEE | | 1 | $2,776 | $2,776.00 |
| PIPING | | 1 | 1000 | $1,000.00 |
| | | TOTAL DC | | $3,776.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $377.60 |
| ENG/DES | % OF DC | | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | | 4% | $151.04 |
| PERMITTING | % OF DC | | 0.5% | $18.88 |
| | | TOTAL IDC | | 925.12 |
| | | TOTAL CAP | | $4,701.12 |
| ANNUAL O&M | | | | |
| USER CHARGE | | 1277500 | $0.02 | $25,550.00 |
| | | TOT AN O&M | | $25,550.00 |
| | | O&M 5 YR | | $113,748.60 |
| | | TOTAL PW | | $118,450 |

001463

NO ACTION (10% INT RATE) "SCENARIO G"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| MATERIAL TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 12 | $75 | $900.00 |
| | | TOTAL DC | $30,700.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $3,070.00 |
| ENG/DES | % OF DC | 5% | $1,535.00 |
| ADMIN/INSPEC | % OF DC | 4% | $1,228.00 |
| | | TOTAL IDC | $5,833.00 |
| | | TOTAL CAP | $36,533.00 |
| ANNUAL O&M | | | |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| | | TOT AN O&M | $40,375.00 |
| | | O&M 10 YR | $248,064.00 |
| | | TOTAL PW | $284,597 |

001464

DEEP WELL INJECTION (10% INT RATE) "SCENARIO G"

| ACTIVITY | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|
| DIRECT COSTS | | | |
| MONITOR WELLS | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | 10 | $1,440 | $14,400.00 |
| PIPING | 1 | $4,300 | $4,300.00 |
| TANK(30000 GALLON) | 1 | $12,000 | $12,000.00 |
| CONTAINMENT | 1 | $8,000 | $8,000.00 |
| GENERATOR | 1 | $1,050 | $1,050.00 |
| FENCE | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | 16 | $75 | $1,200.00 |
| | | TOTAL DC | $77,150.00 |
| INDIRECT COSTS | | | |
| CONT | % OF DC | 10% | $7,715.00 |
| ENG/DES | % OF DC | 7.5% | $5,786.25 |
| ADMIN/INSPEC | % OF DC | 4% | $3,086.00 |
| | | TOTAL IDC | $16,587.25 |
| | | TOTAL CAP | $93,737.25 |
| ANNUAL O&M | | | |
| TRANSPORT | 256 | $600 | $153,600.00 |
| FEE | 11100000 | $0.03 | $333,000.00 |
| WATER SAMP(4/YR-20 WELLS) | 80 | $300 | $24,000.00 |
| BORINGS | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | 25 | $300 | $7,500.00 |
| LABOR | 127.5 | $50 | $6,375.00 |
| GAS | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | $532,137.50 |
| | | O&M 10 YR | $3,269,452.80 |
| | | TOTAL PW | $3,363,190 |

001465

CARBON ADSORPTION (10% INT RATE) "SCENARIO G"

| ACTIVITY | | COST BASIS | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| COLUMN SYSTEM | | 1 | $45,000 | $45,000.00 |
| BUILDING TO HOUSE COLUMNS | | 1 | $4,000 | $4,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $14,350.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $143,500.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $14,350.00 |
| ENG/DES | % OF DC | | 10% | $14,350.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,740.00 |
| | | | TOTAL IDC | $34,440.00 |
| | | | TOTAL CAP | $177,940.00 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 24000 | $2 | $48,000.00 |
| CARBON SAMP | | 52 | $300 | $15,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $109,137.50 |
| | | | O&M 10 YR | $670,540.80 |
| | | | TOTAL PW | $848,481 |

001466

AIR STRIPPING (10% INT RATE) "SCENARIO G"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| STRIPPER | | 1 | $10,000 | $10,000.00 |
| CARBON COL | | 1 | $25,000 | $25,000.00 |
| SERVICE CONTRACT | % DC | | 10% | $12,794.44 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | | TOTAL DC | $127,944.44 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $12,794.44 |
| ENG/DES | % OF DC | | 10% | $12,794.44 |
| ADMIN/INSPEC | % OF DC | | 4% | $5,117.78 |
| | | | TOTAL IDC | $30,706.67 |
| | | | TOTAL CAP | $158,651.11 |
| ANNUAL O&M | | | | |
| CARBON REGEN | | 6000 | $2 | $12,000.00 |
| CARBON SAMP | | 12 | $300 | $3,600.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $61,137.50 |
| | | | O&M 10 YR | $375,628.80 |
| | | | TOTAL PW | $534,280 |

001467

CATALYTIC DEHYDROCHLORINATION (10% INT RATE) "SCENARIO G"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| MONITOR WELLS | | 20 | $1,440 | $28,800.00 |
| RECOVERY WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| TANK(10000 GALLON) | | 2 | $6,500 | $13,000.00 |
| CONTAINMENT | | 1 | $10,000 | $10,000.00 |
| LAB STUDY | | 1 | $22,500 | $22,500.00 |
| PILOT STUDY | | 1 | $225,000 | $225,000.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| FENCE | | 800 | $6 | $4,800.00 |
| DECONTAMINATE EQUIP | | 32 | $50 | $1,600.00 |
| MATERIALS TO PLUG WELLS | | 1 | $1,000 | $1,000.00 |
| EQUIP & LABOR | | 16 | $75 | $1,200.00 |
| | | TOTAL DC | | $327,650.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $32,765.00 |
| ENG/DES | % OF DC | | 10% | $32,765.00 |
| ADMIN/INSPEC | % OF DC | | 4% | $13,106.00 |
| | | TOTAL IDC | | $78,636.00 |
| | | TOTAL CAP | | $406,286.00 |
| ANNUAL O&M | | | | |
| REAGENT | | 5600 | $20 | $112,000.00 |
| WASTE DISPOSAL | | 5600 | $20 | $112,000.00 |
| FIELD LABOR | | 1 | $175,000 | $175,000.00 |
| OFFICE SUPPORT | | 1 | $75,000 | $75,000.00 |
| MAINT | | 1 | $155,000 | $155,000.00 |
| WATER SAMP(4/YR-20 WELLS) | | 80 | $300 | $24,000.00 |
| BORINGS | | 5 | $500 | $2,500.00 |
| SOIL SAMP(5 SAMP/BORING) | | 25 | $300 | $7,500.00 |
| LABOR | | 127.5 | $50 | $6,375.00 |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | TOT AN O&M | | $674,537.50 |
| | | O&M 10 YR | | $4,144,358.40 |
| | | TOTAL PW | | $4,550,644 |

001468

REINJECTION ON-SITE (10% INT RATE) "SCENARIO G"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| INJECTION WELLS | | 10 | $1,440 | $14,400.00 |
| PIPING | | 1 | $4,300 | $4,300.00 |
| GENERATOR | | 1 | $1,050 | $1,050.00 |
| | | | TOTAL DC | $19,750.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | 1975 |
| ENG/DES | % OF DC | | 10% | 1975 |
| ADMIN/INSPEC | % OF DC | | 4% | 790 |
| PERMITTING | % OF DC | | 0.5% | 98.75 |
| | | | TOTAL IDC | 4838.75 |
| | | | TOTAL CAP, | $24,588.75 |
| ANNUAL O&M | | | | |
| GAS | | 3250 | $0.85 | $2,762.50 |
| PUMP/GEN MAINT | | 96 | $25 | $2,400.00 |
| | | | TOT AN O&M | $5,162.50 |
| | | | O&M 10 YR | $31,718.40 |
| | | | TOTAL PW | $56,307 |

001469

DISCHARGE TO POTW (10% INT RATE) "SCENARIO G"

| ACTIVITY | COST BASIS | | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| DIRECT COSTS | | | | |
| CAPACITY FEE | | 1 | $2,776 | $2,776.00 |
| PIPING | | 1 | 1000 | $1,000.00 |
| | | | TOTAL DC | $3,776.00 |
| INDIRECT COSTS | | | | |
| CONT | % OF DC | | 10% | $377.60 |
| ENG/DES | % OF DC | | 10% | $377.60 |
| ADMIN/INSPEC | % OF DC | | 4% | $151.04 |
| PERMITTING | % OF DC | | 0.5% | $18.88 |
| | | | TOTAL IDC | 925.12 |
| | | | TOTAL CAP | $4,701.12 |
| ANNUAL O&M | | | | |
| USER CHARGE | | 1277500 | $0.02 | $25,550.00 |
| | | | TOT AN O&M | $25,550.00 |
| | | | O&M 10 YR | $156,979.20 |
| | | | TOTAL PW | $161,680 |

001470